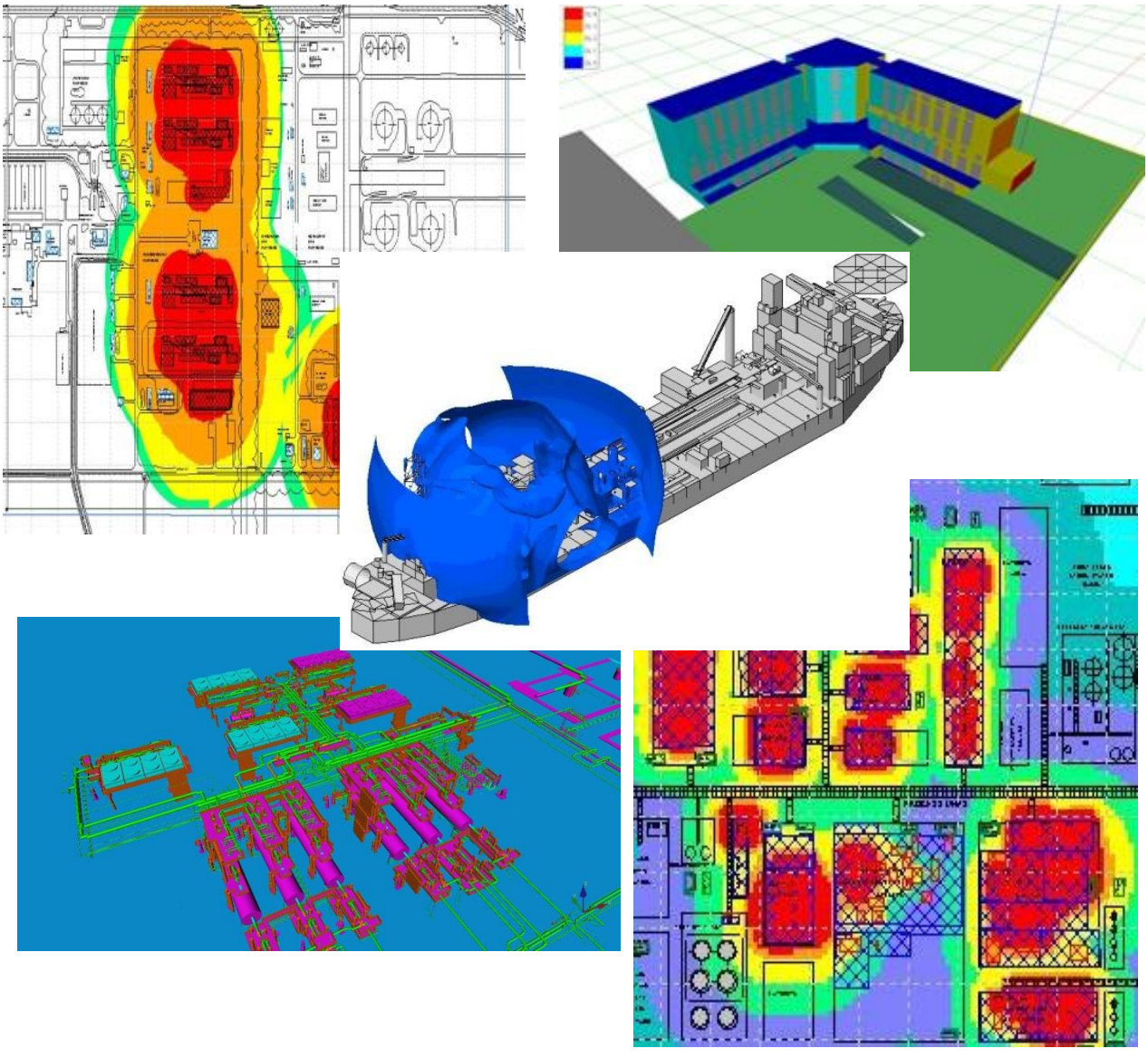
PATRICK MANN & ASSOCIATES

Extreme Loads & Structural Risk Engineers

Statement of Capability
for
QRA Safety Services



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RSES Register of Security Engineers & Specialists

CONTENTS

1 INTRODUCTION

Patrick Mann & Associates Ltd (PMA) is a dynamic and growing consultancy. Its mission is to provide total risk management solutions underpinned by a solid foundation of engineering, science and technology.

PMA's strength is its ability to quantify business, operational and asset risks from natural and man-made hazards, and furnish rational solutions that are a blend of effective management controls, engineering and practical loss-control measures.

The hallmark of our approach is to identify the client's specific needs, and then to develop tailored services that specifically address the client's issues on an integrated basis. As a result we are providing services to a rapidly expanding client base, which includes the Insurance, Defence, Government, Nuclear, Oil & Gas and Transport sectors.

A selection of clients that PMA engineers have undertaken projects for includes:

2 QRA SAFETY SERVICES

Some of PMA's engineers have up to 20 years of experience of performing QRA and BRA safety studies on chemical and petrochemical sites. PMA engineers are actively involved with professional bodies that develop industry best practice, and have also written internal company standards for the assessment and design of buildings. They have a detailed working knowledge of the international best practice blast design criteria including:

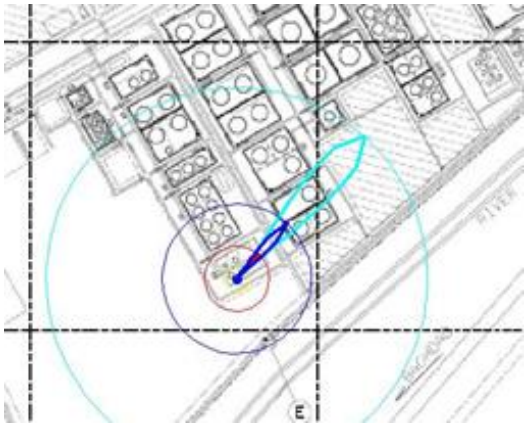
- CIA "Guidance for the Location and Design of Occupied Buildings on Chemical Manufacturing Sites".
- API "Management of Hazards Associated with Location of Process Plant Buildings" Recommended Practice 752.
- ASCE Guide "Design of Blast Resistant Buildings in Petrochemical Facilities".

An overview of the blast related services that PMA can provide is summarised below, while the following pages provide a description of typical services provided by PMA within this area.

- Site Inspection and Hazard Identification (HAZID) Studies
- Financial Loss Assessments
- Incident Investigations
- Load and Performance Criteria Development
- Dispersion Analysis
- Explosion Modelling and Blast Load Prediction using BST, MEM and CAM methods
- Facility Siting Studies
- Occupied Building Risk Assessments OBR)
- Building Risk Assessments BRA)
- Quantitative Risk Assessments (QRA)
- Computational Fluid Dynamic (CFD) Modelling
- Building Vulnerability Screening
- Blast Assessment / Blast Analysis of Building Damage
- Blast Upgrade Feasibility / Cost Benefit Studies
- Blast Design of Risk Mitigation
- Implementation Support / Project Management

Geographically, PMA is UK based. However, PMA engineers have successfully delivered projects across the globe, including Europe, Africa, Middle East, Far East, North America and South America. PMA engineers are therefore familiar with supporting projects within different working environments.

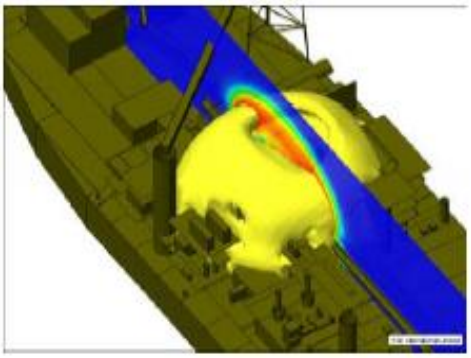
2.1 Fire and Explosion Analysis

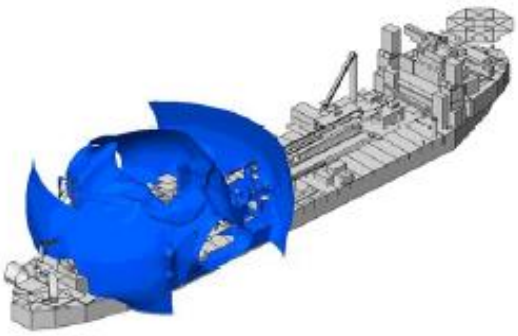


Fire and explosion are undertaken in order to identify and quantify the impact of fire and gas major accident hazards encountered in the oil, chemical and process industries.

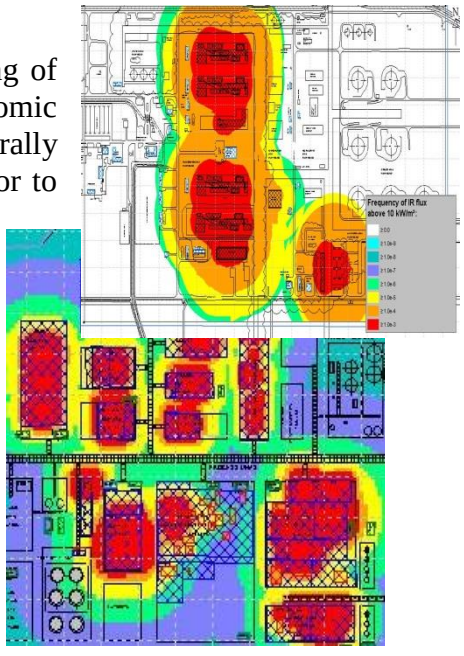
PMA engineers have considerable expertise, and are able to bring experience gained in a wide range of industries to our work. Each study typically involving a blend of advanced modelling/analysis techniques and practical engineering, encompassing:

- Identification of combustion sources and explosive inventories
- Determination of fire and explosion major hazard scenarios and their escalation potential
- Assessment and modelling of Smoke and Gas Ingress
- Assessment of the consequences of such incidents, with the aid of deterministic and probabilistic computing systems
- Audit of fire detection systems
- Audit of active and passive fire and explosion protection





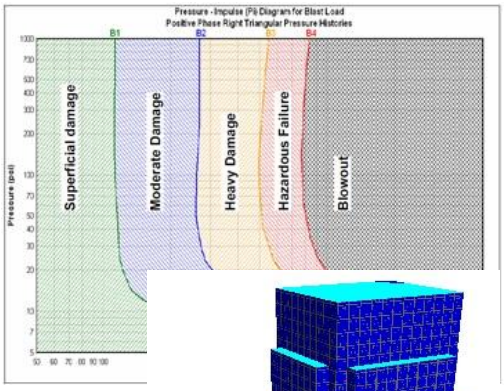
2.2 Quantitative Risk Assessment (QRA)



Quantitative Risk Assessment provides a clear understanding of the potential events that may affect the safe and economic operation of potentially hazardous plant. They are generally undertaken to demonstrate that the site is safety to operate or to justify the adequacy of the site's layout within design studies. Building Risk Assessment (BRA) and Occupied Building Risk (OBR) studies are similar to QRA studies but focus on the risk to the building and its occupants.

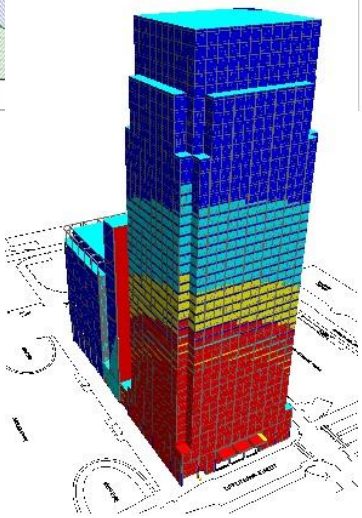
PMA Engineers have significant experience in delivering the QRA, BRA and OBR studies. They have developed processes to systematically evaluate the possible major accident hazards on a site, their consequences and frequency, a quantitatively calculate the risk in order to determine whether the risk is acceptable or not. Typically these studies are supported by software including FRED, SHEPHERD and PHAST.

2.3 Building Damage Evaluation



In order to remove conservatism from the risk assessments, building damage assessment are regularly undertaken. The typical assessment process includes:

- A detailed review of the structural drawings for the building, and a site survey.
- The development of a 3D building model to analysis how the blast loading wraps around the building and loads the individual building components.
- The calculation of pressure-impulse (P-I) vulnerability curves for the key building elements (columns, beams, walls, windows, etc.), which are then mapped onto the model in order to determine the level of building damage.



The analysis output provides a quantification of the expected building damage and maps where the damage, and thus risk, is unacceptable, i.e. the predicted damage carries an intolerable level of asset damage or loss of life potential.

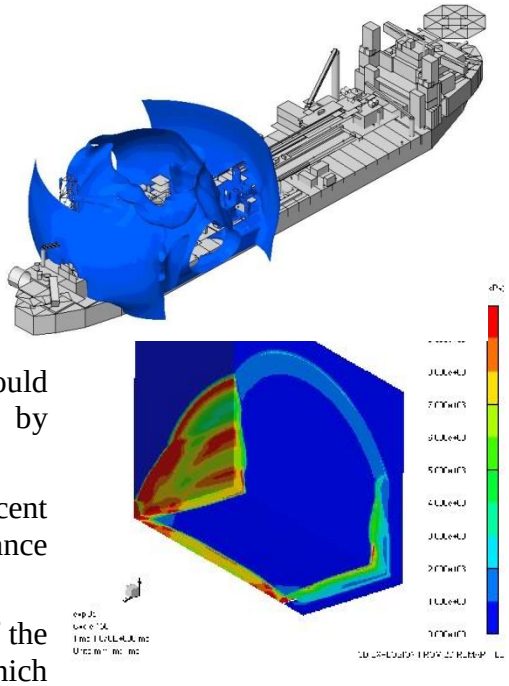
The damage results are then used to direct design option studies to identify the range of strategies that could be used to enhance the building's resilience and thus reduce the risk to an acceptable level.

Cost benefit studies can then be used to assess the strengths and weakness of each upgrade option in order to identify optimum solution.

2.4 Advanced Analysis

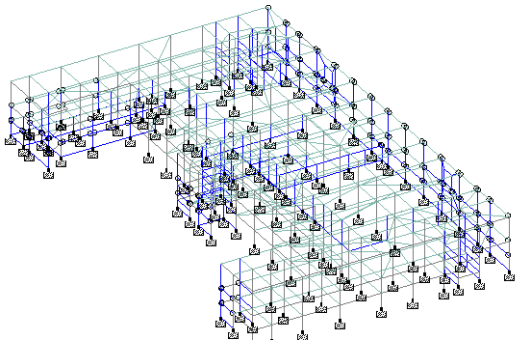
Where the risk is identified as unacceptable, PMA can provide a variety of more in-depth and specialist support services. This may include:

- *Computational Fluid Dynamics (CFD)* studies to provide a more refined prediction of the blast hazard experienced by the building. CFD studies enable detailed consideration of factors such as:
    - Shielding – adjacent structures could reduce the demand to the structure by providing shielding.
    - Reflection – the impact of adjacent structural elements that could enhance the demand.
    - Congestion – a detailed assessment of the level of turbulence generated, which affects the magnitude of the vapour explosion hazard.



- *Finite Element (FE) Analysis* to provide a more detailed assessment of critical aspects of the building. The use of FE analysis can help to remove unnecessary conservatism inherent within the previous P-I diagram approach, since it is able to include factors such as load redistribution.

  It is noted that the use of FE approach is more resource intensive that the P-I approach. However, it can be very cost-effective if used appropriately, as conservatism can be removed from the design.



2.5 Detailed Design

Where the risk is unacceptable, PMA can perform the detailed design activities required to enhance the basic structural design to safely withstand the blast loading. Commonly this is undertaken by fine tuning the detailing within the structure such that it is more resilient to the blast loading. This approach therefore enables the building to provide enhanced protection without compromising the visual appearance of the facility.

The output from the design process depends on the requirements of the design brief. Typical output comprises:

- Performance Specifications, which include design loads and maximum acceptable damage criteria, along with location drawings. The Performance Specification approach is commonly used where the client wishes to tender for "off-the-shelf" solutions.
- Construction Specification, which include complete construction drawings and specifications that can be used by a contractor to build the design.

2.6 Construction Support

Construction Support is commonly requested in order to ensure that the design intent is achieved throughout the implementation process. The level of implementation support is dependent on the engineering capability of the organisation and their contractor. Typically implementation support is limited to:

- Review of technical aspects of tender submissions
- Resolution of any ad-hoc queries during installation, e.g. requests for changes to member specifications or detailing.
- Confirmatory inspections to ensure that the design intent has been achieved.

The output from this workscope is commonly a Certification Statement that the design has been installed in accordance with the design intent.

2.7 Supplementary Services

The above section has focused on the typical QRA Safety Studies services provided by PMA. The below summarises a selection of other services that PMA can provide. Further details of these services can be provided on request.

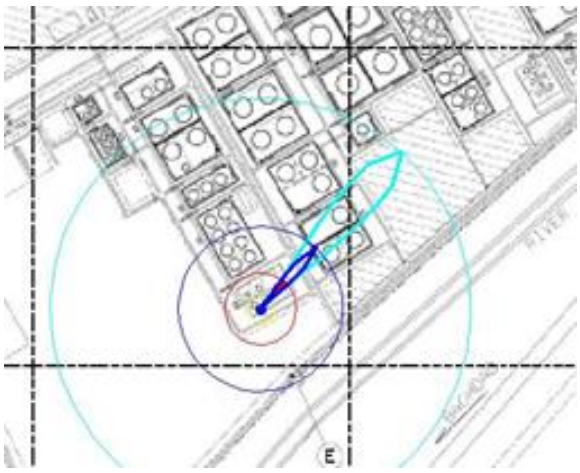
- Probable Maximum Loss (PML) Studies – these are undertaken to evaluate the probable maximum loss from a specific event, e.g. a terrorist attack or earthquake.

These studies are commonly used to support investment decisions or the purchase of insurance.

- Seismic Assessment & Design Studies – these are undertaken to support the design process in areas of moderate or high seismic risk, or for high risk facilities where a regulator has mandated it as a design load case, e.g. the nuclear industry.

3 CASE STUDIES

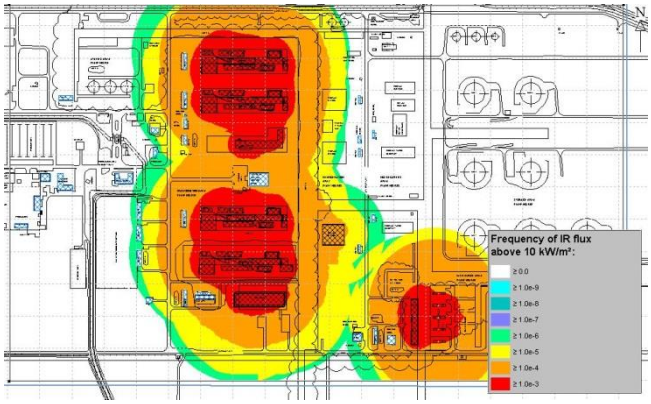
3.1 Study 1 – QRA Refinement Studies



As part of a FEED design project a coarse consequence assessment had been undertaken to assess the impact of the site's major accident hazards. The study conclusions identified major problems with the site layout, which required major redesign. PMA were subsequently requested to perform a QRA refinement study in order to provide a more refined assessment of the site's risk.

The study was undertaken using PHAST and in accordance with API RP 752. The put demonstrated that the risk posed on both on-site and off-site was ALARP. Redesign of the site was not therefore required.

3.2 Study 2 – Building Risk Assessment



PMA Engineers have recently completed four Building Risk Assessment studies, using Shell SHEPHERD for large gas plants in Saudi Arabia.

The study was undertaken to comply with the requirements of Aramco Engineering Standard SAES-B-014 "Safety Requirements for Plant and Operations Support Buildings" and followed the 3 stage process outlined by API RP 752. For each site the study included:

- Detailed identification of hazards and hazard scenarios,
- Consequence analysis using Shell FRED modelling software,
- Building risk analysis using the Shell SHEPHERD risk analysis tool.

The study was aimed at demonstrating that the risks to building occupants is As Low As Reasonably Practicable (ALARP), and where the risks were found to be unacceptable, suitable risk reducing measures (RRM) were developed.

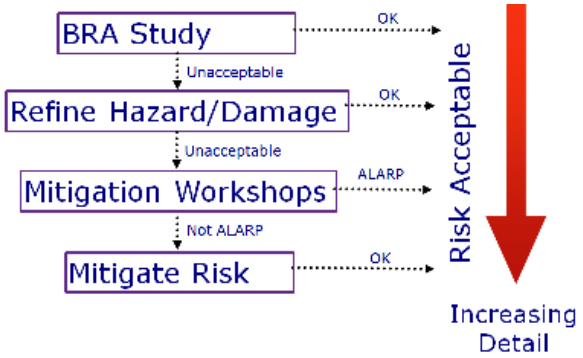
3.3 Study 3 – Building Risk Assessment Master Plan

PMA Engineers have recently completed a BRA Master Plan project for a major Middle East oil producer. The object of the study was to undertake a detailed benchmark study in order to:

- Review the internal standards for compliance with international best practice and to recommend adjustments where necessary.
- Evaluate the inconsistencies in the application of the BRA standards and the impact on the results, and to make recommendations to ensure better consistency in the future.

- Review the various study conclusions, and identify where best practice rules for whether refinement of the study conclusions should be considered.
- Review international best practice for building upgrade in order to develop mitigation guidelines for ensuring consistency and value for money.

The study recommendations are currently being implemented and are being used to drive the building upgrade programme. The implementation of the recommendations has resulted in a 50% reduction in the budget for building upgrade.

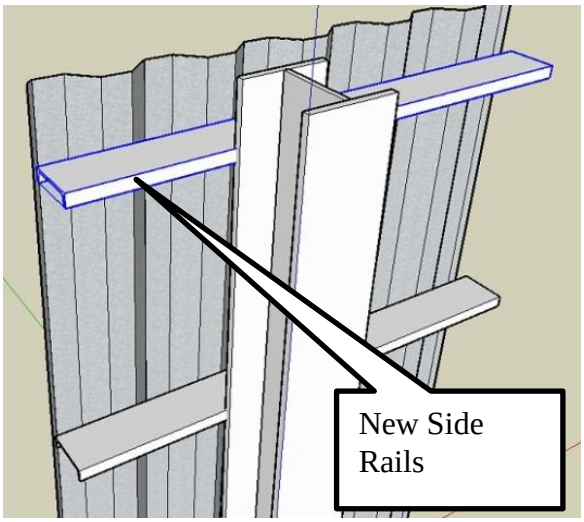


3.4 Study 4 – Upgrade Option Studies

The conclusions from a BRA study had identified that occupants in a number of the site was unacceptable and had recommended upgrade. The recommendations contained limited detail but suggested that building replacement was necessary.

PMA engineers were therefore requested to undertake a detailed assessment on the building in order to identify upgrade options. The study included:

- The evaluation of the blast loading incurred on each portion of the building façade.
- Structural assessments to determine the level of damage incurred by the different areas of the façade.
- The development of upgrade concepts to mitigate the building components shown to be unacceptable.

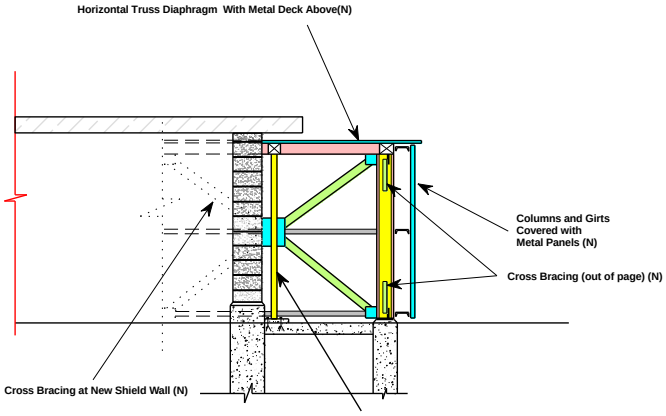


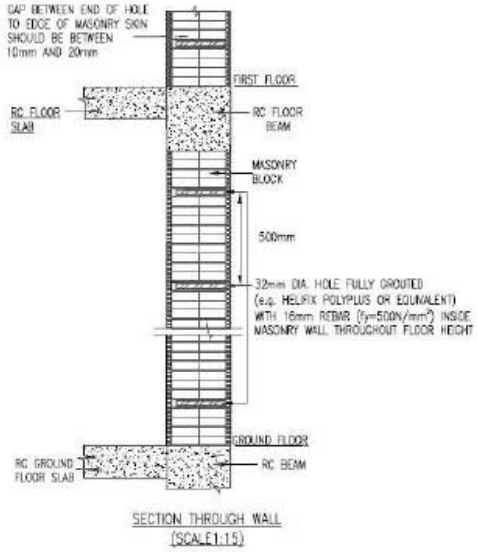
The conclusions of the study were that locally targeted upgrades would be sufficient to reduce the level of risk to an ALARP level. Detailed design schemes were therefore developed.

As a consequence of this study the upgrade budget reduced from in excess of £1million to less than £75,000.

3.5 Study 5 – Building Upgrade

PMA Engineers developed blast upgrade concepts and prepare preliminary design for a number of control room buildings on a petrochemical plant. This included wall and roof upgrade solutions for different blast hazard levels. For the lower hazard levels the schemes included local wall enhancements while for the high demand locations, sacrificial wall skins were designed.





4 CONTACT DETAILS

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