BAKER ENGINEERING AND RISK CONSULTANTS, INC.

BAKERRISK®

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Mr. Chris Greer
Vice President of Sales
Rigid Global Buildings
18933 Aldine Westfield
Houston, TX 77073
Chris.Greer@rigidbuilding.com

Re: Blast Resistant Design for Building ABC
BakerRisk Project 0X-0XXXX-0XX

Dear Mr. Greer:

Baker Engineering and Risk Consultants, Inc. (BakerRisk®) has worked with Rigid Global Buildings (Rigid) to complete the blast resistant design of the Building ABC at the XYZ Company (XYZ) Facility in City, State. BakerRisk provided the blast resistant design requirements such that the pre-engineered steel framed building would meet an ASCE damage level of Medium in response to the design blast loads.

We appreciate the opportunity to perform this study, and look forward to working with you in the future. If you have any questions or comments, please do not hesitate to call me at (210) 824-5960 or email me (THolland@BakerRisk.com).

Sincerely,

Travis J. Holland, P.E.
Senior Engineer

Approval:

Michael A. Polcyn
Manager, Protective Structures

BLAST RESISTANT DESIGN

Draft Report

Date Issued:

BUILDING ABC

Prepared for:

Rigid Global Buildings

CITY, STATE FACILITY

Prepared by:

Travis J. Holland, P.E.

BakerRisk Project No.
0X-0XXXX-0XX

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BakerRisk regards the work that it has done as being advisory in nature. The responsibility for use and implementation of the conclusions and recommendations contained herein rests entirely with the client.

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1 INTRODUCTION

The services of Rigid Global Buildings (Rigid) were engaged to complete the design and fabrication of the pre-engineered steel framing and metal cladding for the Building ABC at the XYZ Company (XYZ) facility in City, State. Rigid retained the services of BakerRisk to complete the blast-resistant design, which included development of the blast-resistant design for the metal cladding, secondary structural members, and lateral system of the building.

The Building ABC has plan dimensions of __ feet (north-south) × __ feet (east-west). The building has an eave height of __feet.

BakerRisk worked with Rigid to incorporate the blast-resistant requirements into the design drawing package. BakerRisk reviewed the structural steel framing and steel connections detailed in the Rigid drawings and provided minor comments that will be incorporated in the Issued for Construction set. With the incorporation of the final BakerRisk comments the structural steel design will meet the project blast requirements.

This report provides a summary of the typical structural framing required to meet the blast-resistant criteria established for this project. Non-typical framing and connection details can be located in the Rigid drawings attached to this report (see Appendix A.)

2 Blast Loads and Response Criteria

Design blast loads and response criteria for the Building ABC building were provided in the project bid package. A summary of the design blast loads is provided in Table 1. The pressure- time history profile for the blast loads is assumed to follow an idealized shock profile (i.e., instantaneous rise in pressure followed by a linear decay to ambient). Note that the south and west elevation building face the processing facility and will be subjected to a reflected overpressure.

All structural components are designed to meet the Medium response criteria as described by the American Society of Civil Engineers (ASCE)[1] and summarized in Table 2 and Table 3.

Table 1. Summary of Design Blast Loads

Surface	Scenario	Pressure (psi)	Impulse (psi-ms)
Roof	1	0.3	70
	2	0.6	30
South	1	0.6	140
	2	1.2	60
East	1	0.3	70
	2	0.6	30
North	1	0.3	70
	2	0.6	30
West	1	0.6	140
	2	1.2	60

[1] Design of Blast Resistant Buildings in Petrochemical Facilities, prepared by the Task Committee on Blast Resistant Design of the Petrochemical Committee of the Energy Division of the American Society of Civil Engineers, 2010.

Table 2. ASCE Response Criteria

Component Damage Level	Damage Description
Low	Component has none to slight visible permanent damage.
Medium	**Component has some permanent deflection. It is generally repairable, if necessary, although replacement may be more economical and aesthetic.**
High	Component has not failed, but it has significant permanent deflections causing it to be unrepairable.

Table 3. ASCE Criteria for Medium Response

Component Type	Support Rotation (degrees)	Ductility
Cold Formed Steel Panels	2	3
Cold Formed Girts / Purlins	3	3
Hot Rolled Secondary Members	6	10
Hot Rolled Primary Members without Significant Compression	2	3
Frame Sway	Frame Sway < Height / 35 (Building Height = ___, Frame Sway = _)	

3 Blast Resistant Design

Sizing of structural components under the predicted blast loads was determined by modeling the components as Single-Degree-of-Freedom (SDOF) systems. The SDOF model for each component was constructed using the component's mechanical properties so the model would exhibit the same displacement history as the point of maximum deflection in the component.

The calculated peak deflection was used to determine the support rotation and ductility ratio, which represent the deformation limit criteria most commonly used in blast design (Table 3).

The structural analysis methodology utilized in this effort can be found in structural dynamics textbooks such as the one by Biggs,[2] in blast design manuals such as the ASCE handbook,[1] and in the DoD's UFC 3-340-02.[3]

BakerRisk and Rigid coordinated the preliminary blast resistant design in support of a bid package. Following the project being awarded, BakerRisk completed a comprehensive blast resistant design of the Building ABC.

3.1 Secondary Structural Members and Cladding

3.1.1 Grid Line A – West (Reflected)

BakerRisk provided sizing and reaction information for the metal panels and the steel girts at Grid Line A. A summary of the typical girts on the west wall (Grid Line A) of the building is provided in Table 4. The cold-formed sections are predicted to deflect up to X" into the building in response to the design basis loads. The cold-formed girts span over the outside face of the rigid frame column and are spliced. The splice connection uses a total of X A325 bolts. The splice connection is detailed in the Rigid drawing package attached to this report (see Appendix A).

[2] Biggs, J.D., *Introduction to Structural Dynamics,* McGraw-Hill Publishing Company, New York, 1964.
[3] Department of Defense, *Structures to Resist the Effects of Accidental Explosions*, UFC 3-340-02, 1 December 2008.

Table 4. Summary of Typical Framing – West Wall

Frame Line	Member	Span (ft)	Spacing (ft)	ASCE Response Level
1-2	Cold formed girt	20	X	Medium
2-3	Cold formed girt	20	X	Medium
3-4	Cold formed girt	25	X	Medium
4-5	Cold formed girt	25	X	Medium
5-6	Cold formed girt	25	X	Medium
6-7	Cold formed girt	25	X	Medium
7-8	Cold formed girt	20	X	Medium
8-9	Cold formed girt	20	X	Medium

The girt immediately above and / or below a wall opening is designed to resist the blast loading over the increased tributary area. A summary of sizing requirements is provided in Table 5. The hot rolled sections are connected to the outside flange of the rigid frame column with A325 bolts.

Table 5. Summary of Framing at Openings – West Wall

Opening Height (H)	Member	Span (ft)	ASCE Response Level	Design Shear Reaction (lbs)
H < 5'	Hot rolled girt	20 - 25	Medium	XX,000
5' < H < 20'	Hot rolled girt	25	Medium	XX,000
H > 20'	Hot rolled girt	20	Medium	XX,000

There is a single overhead rollup door and a single personnel door on the Grid Line A elevation. The vertical jambs at the overhead door are hot-rolled sections (A36 steel), and the vertical jambs at the personnel door are hot-rolled sections (A36 steel).

BakerRisk did not provide a review or design guidance for the overhead rollup door panels or the personnel door panels.

The typical metal cladding on the four exterior wall elevations is the light gauge metal panel. The wall panel is secured to the horizontal framing with Hex Head screws at the spacing shown on the Rigid drawings attached to this report (see Appendix A.) The wall panel is calculated to meet a Medium level of response.

3.1.2 Grid Line H – East (Side-On)

The typical girt at the East elevation is a cold-formed zee section. Cold-formed sections are predicted to deflect up to X" into the building in response to the design basis loads. The cold-formed girts span over the outside face of the rigid frame column and are spliced. The splice connection uses a total of X A325 bolts. The splice connection is detailed on Detail X of the Rigid drawing package (see Appendix A.)

The girt immediately above and / or below a wall opening is designed to resist the blast loading over the increased tributary area. A summary of the sizing requirements is provided in Table 5. The hot rolled sections are connected to the outside flange of the rigid frame column with X A325 bolts.

3.1.3 Grid Line 1 – North (Side-On)

The typical girt at the East elevation is a cold-formed zee section. Cold-formed sections are predicted deflect up to X" into the building in response to the design basis loads. The cold- formed girts are connected to the web of the end wall columns with shear tab connection consisting of A325 bolts. The typical connection is detailed on Detail X of the Rigid drawing package (see Appendix A.)

The typical end wall column on the north elevation is a [Steel Shape]. The end wall column is connected to the rigid frame girder and the concrete foundation. The connections are designed to resist a reaction force of XX,000 lbs (oriented into and away from the building).

The framing around the overhead door and personnel door on the north elevation is consistent with the east elevation.

3.1.4 Grid Line 9 – South (Reflected)

The typical girt at the East elevation is a cold-formed zee section. Cold-formed sections are predicted to deflect up to X" into the building in response to the design basis loads. The cold-formed girts are connected to the web of the end wall columns with shear tab connection consisting of X A325 bolts. The typical connection is detailed on Detail X of the Rigid drawing package (see Appendix A.)

The typical end wall column at the south elevation is a [Steel Shape]. The end wall column is connected to the rigid frame girder and the concrete foundation. The connections are designed to resist a reaction force of XX,000 lbs (oriented into and away from the building).

The framing around the overhead door and personnel door on the south elevation is consistent with the west elevation.

3.1.5 Roof Framing

BakerRisk provided sizing and reaction information for the metal roof cladding and the steel roof purlins. The typical roof purlin is a cold-formed zee section, and is predicted to deflect up to X" into the building in response to the design basis loads.

The cold-formed purlins span over the outside face of the rigid frame girder and are spliced. The splice connection uses a total of X A325 bolts. The splice connection is detailed on Detail X of the drawing package (see Appendix A.)

BakerRisk also evaluated the corrugated metal roof deck. The roof panel is secured to the roof framing with Hex Head screws and is calculated to meet a Medium level of response.

3.2 Lateral Resisting System - Bracing

The lateral resisting system in the long direction (north-south) of the building consists of:

- Diagonal roof bracing in Bays ___and ___
- Along Grid Line A, diagonal bracing in Bays ___and ___
- Along Grid Line H, diagonal bracing in Bays ___and ___

The diagonal roof bracing consists of ASTM A36 rod. The roof purlins that are in-line with the compression strut of the diagonal roof bracing are XX heavier gauge sections.

The diagonal wall bracing will be hot-rolled steel angles. The gusset plate connection between the rigid frame column and the angle braces should be designed for a tension force of XX,000 lbs. The wall bracing is anchored to the foundation through the rigid column base plate, and compression struts within the braced walls are steel tube sections.

3.3 Lateral Resisting System – North / South

The lateral resisting systems utilized in the north – south direction are the rigid moment frames. Given the varying conventional loading conditions present within the (e.g., location of an interior mezzanine and an overhead crane within the building), Rigid provided four frame designs for the various frame lines in the building as shown below:

- Frame Lines ___
- Frame Line ___
- Frame Line ___
- Frame Line ___

The column, girder, and sway modes were analyzed for each of the frame designs using SAP2000.[4] For each individual model, a non-linear dynamic analysis was run along with a non- linear pushover analysis. The purpose of this was to generate an SDOF model using the results from the pushover analysis to compare to the dynamic results. Renderings of the SAP2000 frame models are provided in Figure 1 and Figure 2.

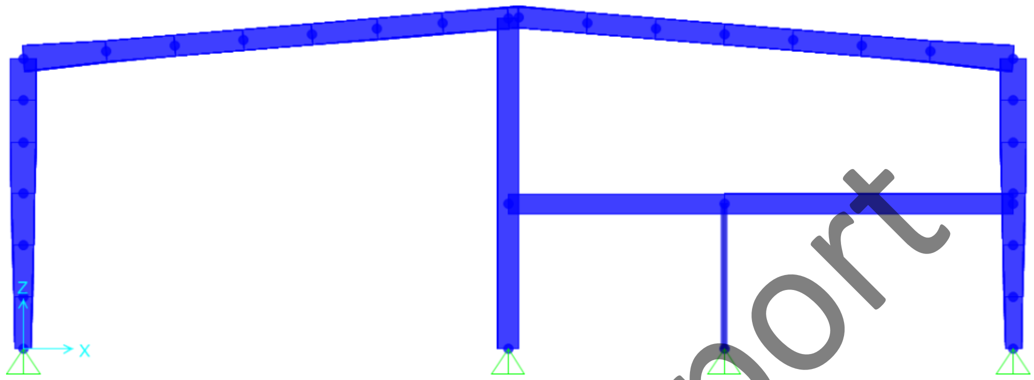

Figure 1. SAP2000 Rendering – Frame Line __

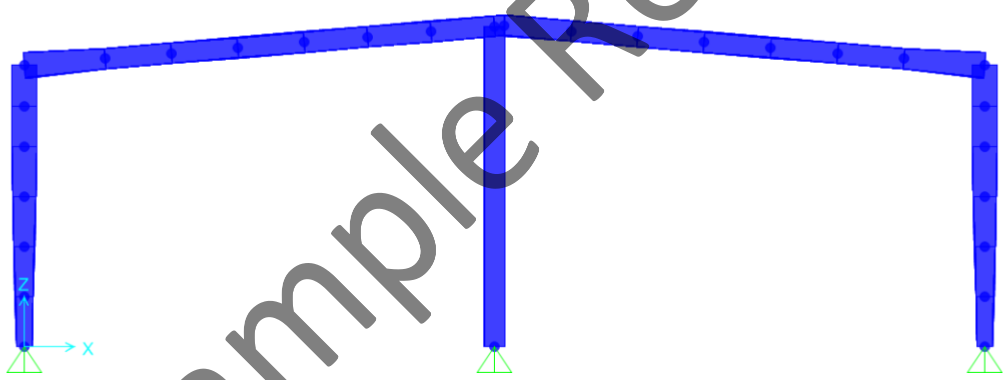

Figure 2. SAP2000 Rendering – Frame Line __

The frames, with dimensions shown in the drawings in Appendix A, will respond at a Medium level of damage in response to the design basis loads. BakerRisk provided Rigid with the dynamic moment demand at the haunch and eave of each moment frame and assisted in the detailing of the moment connections.

The controlling base shear at the rigid frame columns is XX,000 lbs (into the building) and the controlling uplift force at the rigid frame columns is XX,000 lbs. The shear and uplift values should be used by Rigid for the design and detailing of the column base plates (e.g., plate thickness and number of bolts).

[4] *SAP 2000 Version XX,* Computers & Structures Inc. (CSi)

APPENDIX A: CLIENT NAME DRAWING PACKAGE