IMPROVING SAFETY PROVISIONS OF STRUCTURAL DESIGN OF CONTAINMENT AGAINST EXTERNAL EXPLOSION

Submitted by

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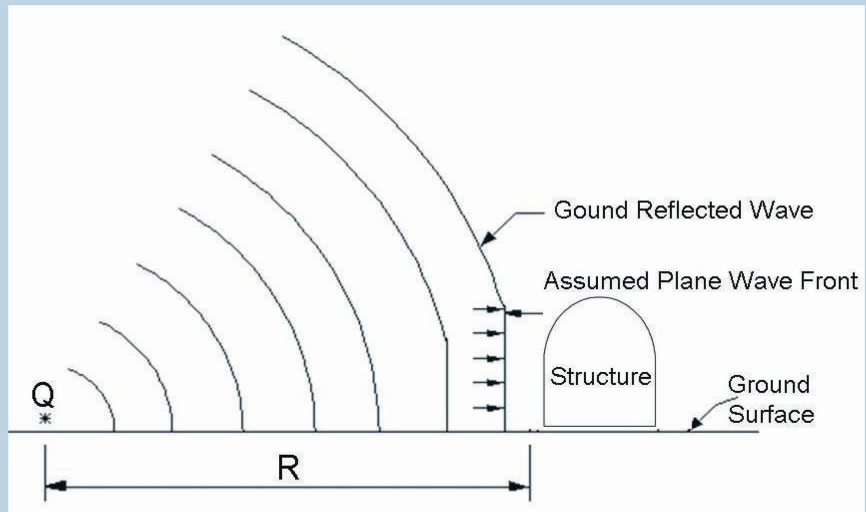
INTRODUCTION

- The work deals with the experimental determination of relationships of simultaneous ground shock and airblast parameters against impulsive loading.
- The empirical relationships of peak air pressure, peak reflected airblast pressure along the height of the structure, peak ground acceleration, arriving shock of ground shock, duration of ground shock and the time lag between ground shock and airblast pressure reaching the concrete structure etc. on a Reinforced Concrete containment scaled model owing to a surface explosion at a certain distance have been established.

Factors affecting Blast Loading On Reactor Containment

1) The magnitude of the explosion.
2) The location of the explosion relative to the structure in question i.e. unconfined or confined explosions.
- The unconfined explosions include free air burst explosion, surface burst explosion.
- The confined explosions include fully vented explosions , partially confined explosions, fully confined explosions.
3) The geometrical configuration of the structure.
4) The structure orientation with respect to the explosion and the ground surface

Surface Burst Blast Environment



Scope of Impulse Loads in ACI 359

- ACI Standard 359 "Code for Concrete Reactor Vessels and Containments" deals with the impulse loads as time dependent loads e.g. the dynamic effects of accidental pressure P_a, the effects of pipe rupture reactions R_{rr} and Jet impingement loading R_{rj} etc.
- The U.S. Nuclear Regulatory Guides does not require consideration of explosions due to terrorist attack and other act of war in the design of Nuclear Power Plant structures.

Relationships between Scale Model And Full Scale Parameters

- **Scale-model experiments may be used to study the explosions effect, but scaling effects must be considered in interpreting the results**

Parameter value	Full-scale value	Scale-model
Dimension	x	Sx
Area	A	S^2A
Volume	V	S^3V
Charge weight	Q	S^3Q
Charge standoff	R	SR
Scaled standoff	$R/Q^{1/3} = Z$	$SR/(S^3Q)^{1/3} = Z$
Pressure	P	P
Impulse / unit area	I	SI
Velocity	v	v

Experimental Set Up & Explosion Scenario

Typical Experimental Values of Shock Wave Propagation in the Air from various Charge Weights

R (m)	Q(kg)	P_{so} (Mpa)	T_a (msec)	T_r (msec)	T_d (msec)	T (msec)	P_{ro} (msec)
5	1	0.047	8	13	1	14	0.033
10	3	0.025	15	17	3	20	0.015
15	5	0.016	22	22	4	26	0.008
20	15	0.018	25	20	7	27	0.010
25	25	0.017	29	21	9	30	0.008

Developed Relationships

I. **Peak Air Pressure in the air**

$$P_{so} = 1.017\ (R/Q^{1/3})^{-1.91} \quad \text{(MPa)} \qquad 12 \geq R/Q^{1/3} \geq 1$$

II. **The Shock Wave Front Arrival Time**

$$T_a = 0.40\ R^{1.2}\ Q^{-0.2}/C_a \quad \text{(s)}$$

III. **The Duration of the Positive Pressure Phase of the Shock Wave**

$$T_+ = T_r + T_d \quad \text{(s)}$$

$$T_r = 0.0026\ (R / Q^{1/3})^{0.98}$$

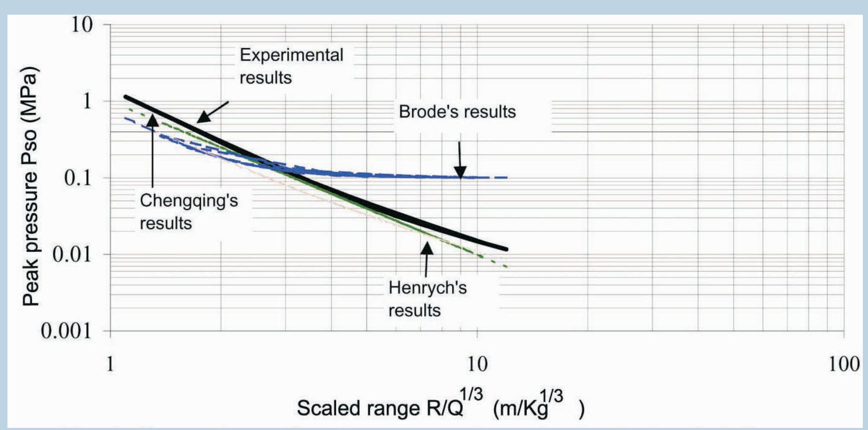
$$T_d = 0.0003\ (R / Q^{1/3})^{0.89} Q^{0.47}$$

$$T_+ = 0.0026\ (R / Q^{1/3})^{0.98} + 0.0003\ (R / Q^{1/3})^{0.89} Q^{0.47}$$

Typical Experimental Values Of Ground Shock with Various Charge Weights

R (m)	Q (Kg)	$R/Q^{1/3}$ ($m/Kg^{1/3}$)	PPA (m/s^2)	T_a (msec)	T_d (msec)
5	1	5	5.6	3	13
10	3	6.96	6.5	7	19
15	5	8.82	6.3	11	24
20	15	8.64	12.3	15	28
25	25	6.87	14.9	20	32

Comparison Of Peak Pressure Attenuation Against Scaled Distance With Other Researchers



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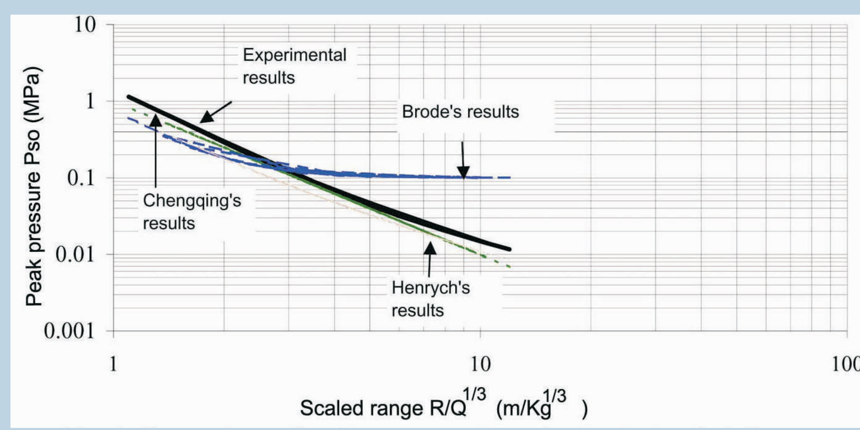
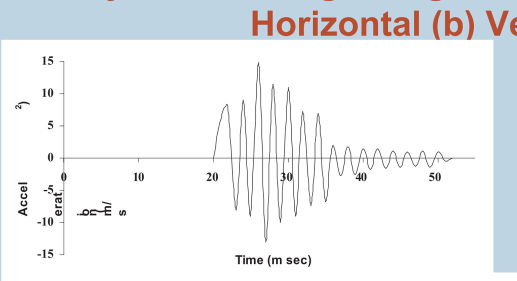
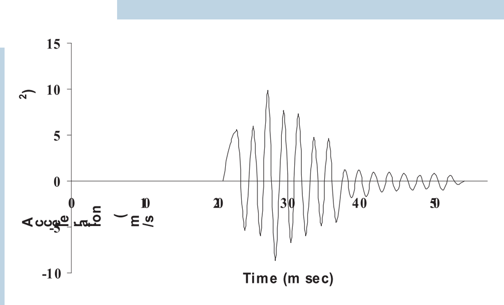


Acceleration Time Histories on Saturated Sandy Clay with a charge weight of 25 Kg at 25 m (a) Horizontal (b) Vertical





Developed Relationships

I. Peak Particle Acceleration

$$PPA = 4.689\ R^{-1.3} Q^{0.95} \quad \text{(g)}$$

II. Ground Shock Arrival time

$$t_a = \frac{0.58 R^{1.24}}{Cs\ Q^{0.01}} \quad \text{(s)}$$

III. Shock wave duration

$$t_d = 0.0056\ R^{0.54} \quad \text{(s)}$$

IV. Time lag between ground shock and airblast pressure arrival at structures

$$T_{lag} = T_a - t_a = 0.40\ R^{1.2}\ Q^{-0.2}/C_a - \frac{0.58\ R^{1.24}}{Cs\ Q^{0.01}} \quad \text{(s)}$$

CONCLUSIONS

OVERPRESSURE IN THE FREE AIR FROM SURFACE EXPLOSION

- The relationship between following parameters of overpressure in the free air from surface explosions have been established through experiment on 1/10th scaled reactor containment model.
  - Peak pressure P_{so} and scaled distance ($R/Q^{1/3}$)
  - Shock wave front arrival time in terms of distance (R) and charge weights (Q)
  - Rising time from arrival time to the peak value (T_r)
  - Decreasing time from peak to the ambient pressure (T_d)
  - Duration of the positive pressure phase of the airblast pressure wave (T)
  - Relation of the peak reflected pressure (P_{ro}) to the peak free air pressure (P_{so})

GROUND SHOCK WAVE FROM SURFACE EXPLOSION

- The relationship between following parameters of Ground Shock Wave from surface explosion have been established.
  - Peak Particle Acceleration (PPA)
  - Arrival Time (t_a)
  - Shock Wave Duration (t_d)
  - Time lag between ground shock and air blast pressure arrival at structures (T_{lag})
- The experimental results have been compared with previous researchers findings. The results variation may be attributed to the curvature of the structure.