Clearing of blast waves from building facades

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The research for this paper has provided some valuable pieces of data towards completing the jigsaw puzzle of the phenomenon of blast clearing. The following observations arise, focusing on impulse values.

17. The subject paper reports on free air bursts at close-scaled distances. The authors concluded that: '... for design purposes, the use of ConWEP and similar databases that consider infinite reflecting surfaces would be a satisfactory basis for conservative design.' This conclusion held good despite the fact that a TNT impulse equivalency of 1·15 was assumed for the PE4 explosive, whereas the tests demonstrated an equivalency of about 0·5 (derived from Fig. 7 in the paper).

18. This conclusion concurs with the results of the majority of medium- to far-distance surface burst trials reported on in Reference 1 in the subject paper and some subsequent full-scale trials. Indeed, in most cases the average impulse calculated using the ConWEP routine for the face of a finite target could safely be used at the target centre. This routine yields a lower value than that calculated for the centre or that for an infinite facade. TNT impulse equivalencies for PE4 approaching 0·5 at close distances were also detected.

19. However, a reverse conclusion was detected in some tests at close stand-off, as remarked on in the abstract to Reference 1. This was confirmed in a subsequent trial series at close stand-offs conducted in 1997 to determine appropriate classifications for the European Standard Range (Arena) Test. The charges were 3–20 kg TNT spheres. At distances from 3 to 6·5 m, measured values at the centre of the targets consistently exceeded 33% more than the average values and significantly more than the local point values calculated by ConWEP for finite targets. During 13 firings the mean of the measured impulses near the base of the target was 21% more than that calculated by ConWEP, where there was effectively no clearing reduction. Even the mean measured reflected impulse over the central (window target) area was up to 10% more than the ConWEP value at the base of the target for an infinite surface. This is despite the measured side-on equivalency being within 1%. In such circumstances the final conclusion in paragraph 15 of the subject paper would not be supported. It would not be conservative to rely on ConWEP calculations, whether for finite or infinite targets.

20. As suggested in the subject paper, the degree of clearing is likely to be related to the ratio of half the target dimension over the stand-off, the tangent of which is the angle of incidence. These values are listed for different trial series in Table 1. Reading from right to left it would be expected that ConWEP would not be conservative for angles more than about 8–11°. Yet the subject paper tests buck the trend, despite angles of 16–34°.

21. The anomaly raises questions about the differences between the subject paper tests (free air bursts and circular targets) and the other trials referred to in this discussion paper (surface bursts and rectangular targets) which more typically reflect real-life scenarios. Further work needs to be done on measuring baseline reflected impulses against large (infinite) surfaces. It would be helpful for tests to be done against rectangular targets for direct comparison with ConWEP. A factor may be the proportionally high dynamic pressure component at close distances. Clearly, further research is needed.

Authors' reply

Paragraphs 17 and 18 of the written discussion comment on the fact that the observed TNT equivalence of Demex high explosive used in the small-scale trials was approximately 0·6, based on the side-on free air measurements described in the paper. A review of the pressure-time histories, from which impulses have been derived, has confirmed that the equivalency is approximately 0·6. The authors do not have any firm proposals to account for this result (other than the comments in paragraph 8 of the original paper). It is suggested, however, that if this approach is continued, a more complete description of the equivalency of Demex (and other commercially available plastic explosives) may result at a future date.

23. Paragraph 19 describes a series of tests where measured impulses on finite targets were significantly greater than local point values calculated by ConWep. This occurred, despite the fact that side-on equivalency was within 1%.

24. The method used by ConWep to calculate the impulse on finite structures is based on

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Table 1. Comparisons of values from different blast trials

Trial series	May 1999 paper RMCS	European Standard Trials 1997	European Standard Trials 1997	Numerous other Trials
Type of burst	Close free air bursts	Fairly close surface bursts	Medium-close surface bursts	Medium/far surface bursts
Actual charges	17·4–43·5 g PE4	3–20 kg TNT	3–20 kg TNT	Various small car to lorry
Actual stand-offs: m	0·3–0·5	3–6·5	> 8	10–200
Scaled stand-offs: m/kg$^{1/3}$	0·8–1·5	1·5–3·8	Up to 6·5	2·5–15
Target radius/stand-off = tangent (angle of incidence to edge of target)	0·67–0·29	0·4–0·2	< 0·15	0·09–0·02 + 0·2 (1 test)
Angle of incidence of edge of target	34–16°	22–11°	< 8·5°	5–1·1° + 11° (1 test)
Measured value; compare ConWEP average for finite surface	?	> ConWEP (33% more over centre)	= ConWEP	= ConWEP (> ConWEP when closer)
Measured value; compare ConWEP for infinite surface	< ConWEP	> ConWEP (21% more at base of target)	< ConWEP	< ConWEP
Thus, ConWEP for infinite surface is apparently	Conservative	Not conservative	Conservative	Conservative

the scaled blast parameters of Kingery and Bulmash[12] for a hemispherical surface burst. Explosive trials, however, rarely achieve truly hemispherical conditions because of the devastating effect this has on the test arena in terms of the creation of debris, energy losses in cratering and the enhanced fragment hazard to test personnel and instrumentation. Therefore, it is normal trials procedure to utilize a separation distance between the charge and the ground surface. This is referred to as a 'height of burst' geometry. At large scaled stand-off distances, the difference in measurable blast resultants (pressure and impulse) between a hemispherical surface burst and a height of burst test arrangement is insignificant. At small scaled stand-off, however, the difference in geometry cannot be ignored, because a height of burst arrangement will always produce pressures and impulses significantly greater than a hemispherical surface burst. Clearly, this effect did not occur in the series of small scale trials reported in the paper, because the loads were developed from spherical charges in free air. It must be concluded that the suggestion in the final comment of paragraph 19, that ConWep might not be conservative at short-scaled range, is certainly valid, if loading geometries other than a hemispherical surface burst are considered.

25. Paragraph 20 discusses the influence of target dimension and angle of incidence on the effect of blast wave clearing. The original paper contains two graphs (Figs 11 and 12) that demonstrate the variation of impulse across structures of constant size with scaled stand-off; these are simply intended as an illustration. It will be appreciated that, because four different charge weights were used in development of the graphs, they do not correspond to a constant scaled structure size, and this, together with the scaled charge stand-off, is the parameter governing the extent of clearing. It is not correct to suggest that the angle made by the edge of the plate is a relevant parameter, because the angle does not have regard to the charge size or any other scaled geometrical parameter. The paper does not make this association.

26. Paragraph 21 suggests that a proportionally high component of dynamic pressure may account for observed increases in impulse at small scaled range. The method of calculating the front face loads on finite structures has not changed significantly since it was first described by Glasstone and Dolan[13] for the effects of nuclear weapons. All the existing procedures, including ConWep, describe the value of pressure to which the reflected pressure reduces (due to clearing) as the incident (side-on) pressure plus a component of dynamic pressure. The dynamic pressure is a function of the (undefined) upstream velocity and density, just ahead of the stagnation region in front of the structure; it is associated with the incident pressure at each moment during the upstream pressure-time history. It is possible to imagine the applicability of this approach, if the structure is a considerable distance from a large explosion, where the overpressure is very low and the duration is very long, because this would give rise to a condition of near-steady incompressible flow behind the shock front. However, for relatively high-pressure, short duration blasts, the notion of dynamic pressure (as it is described by ConWep, for example) is not applicable.

27. The authors of the paper consider that the influence of the experimental geometry (height of burst, discussed earlier) is a more

likely explanation, and the influence of this consideration is easily demonstrated by experiment or numerical simulation.

References

12. Kingery C. N. and Bulmash G. *Airblast Parameters from Spherical Air Blast and Hemispherical Surface Burst*. US Army Armament Research and Development Center, 1984, Technical Report ARBRL-TR-02555.
13. Glasstone S. and Dolan P. J. *The Effects of Nuclear Weapons*. United States Department of Defense and United States Department of Energy, 1977, 3rd edn.