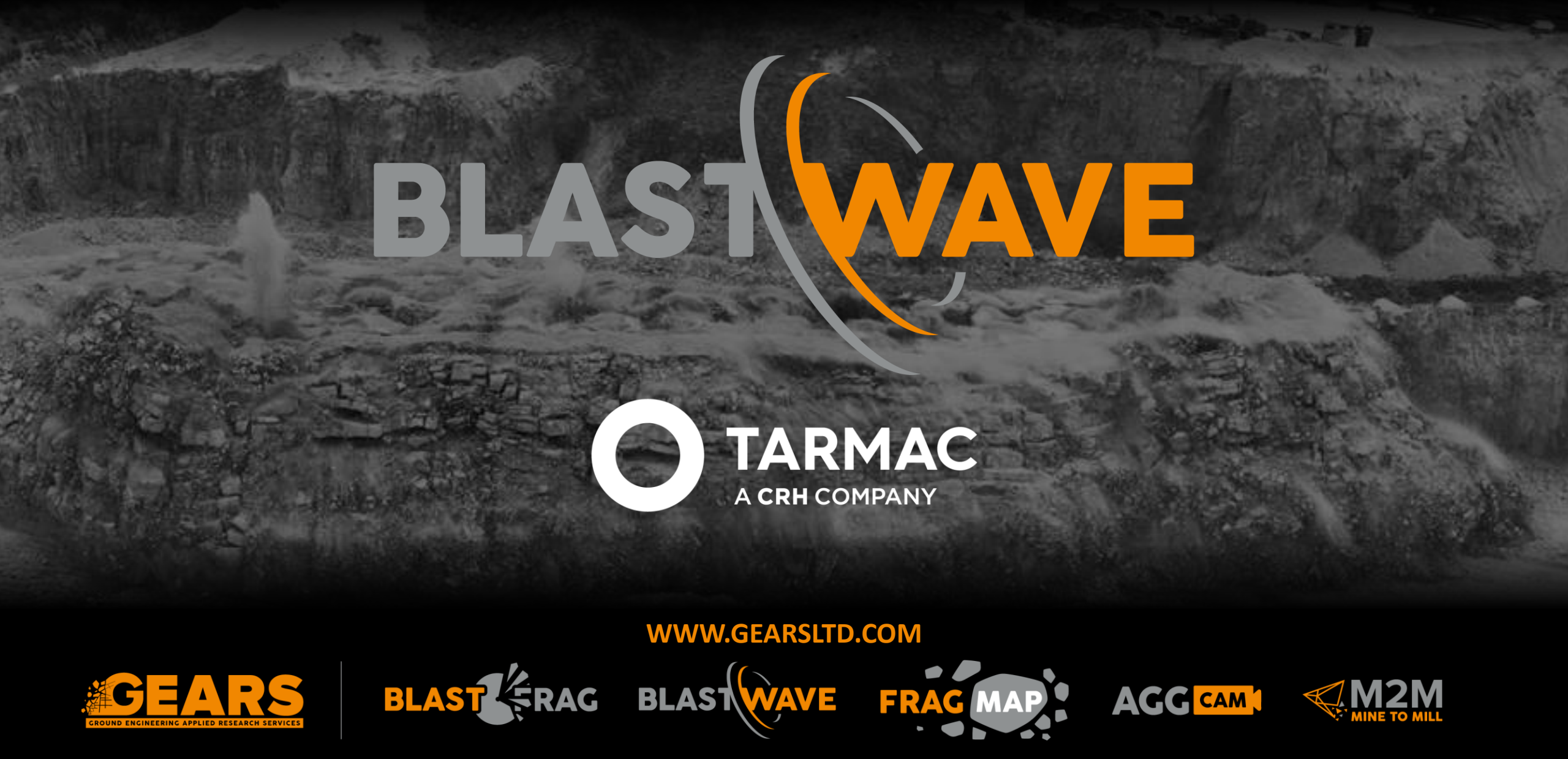
RTPI
Royal Town Planning Institute

WE'RE HAVING A BLAST

mpa
essential materials
sustainable solutions



WWW.GEARSLTD.COM

GEARS
GROUND ENGINEERING APPLIED RESEARCH SERVICES

BLAST FRAG | BLAST WAVE | FRAG MAP | AGG CAM | M2M MINE TO MILL

TARMAC
A CRH COMPANY

GEARS
GROUND ENGINEERING APPLIED RESEARCH SERVICES

BLAST WAVE

PLANNING POLICY | BLAST DAMAGE | NUISANCE IMPACT | CO_2 EMISSIONS | BLAST MONITORING | BLAST OPTIMISATION | EIA

- Most comprehensive engineering assessment of quarry blasting impact to date
- Taken over a decade to compile
- Several million pounds of major infrastructure and quarry blasting projects have facilitated development of technical understanding
- Supported by a 3+ year partnership between Tarmac and GEARS

BLASTWAVE

PLANNING POLICY | BLAST DAMAGE | NUISANCE IMPACT | CO_2 EMISSIONS | BLAST MONITORING | BLAST OPTIMISATION | EIA

PROJECT CONCLUSION

PLANNING – WHAT ARE THE ISSUES?

For quarry blasts we are often:

- Quoting the wrong damage limits
- Not accurately measuring ground vibration
- Not correctly measuring air overpressure
- Not determining what is causing nuisance
- Not measuring nuisance

PROJECT CONCLUSION

PLANNING - WHAT ARE THE CONSEQUENCES?

- Policy and Standards are conflicted
- Not reducing complaints despite ever lowering PPV limits
- Poor fragmentation is increasing CO_2 emissions by up to 21% (1kg/t)
- Costing ~~operators~~ (the taxpayer) up to £2 extra per tonne
- Failed to convince the public that blasting will not cause damage

PROJECT RECOMMENDATIONS

PLANNING - CONTROLS

We should be adopting:

- Separate controls for blast damage and nuisance
- Blast damage limit should be no lower than a PPV of 50mm/s*
- Nuisance limit should be no lower than a PPV of 12 mm/s
  - Subject to scheme of monitoring and improvement
  - Ground vibration and air blast impacts should be considered
- A new nuisance measure should be trialled

* Subject to assessment

PROJECT RECOMMENDATIONS

PLANNING – AWARENESS

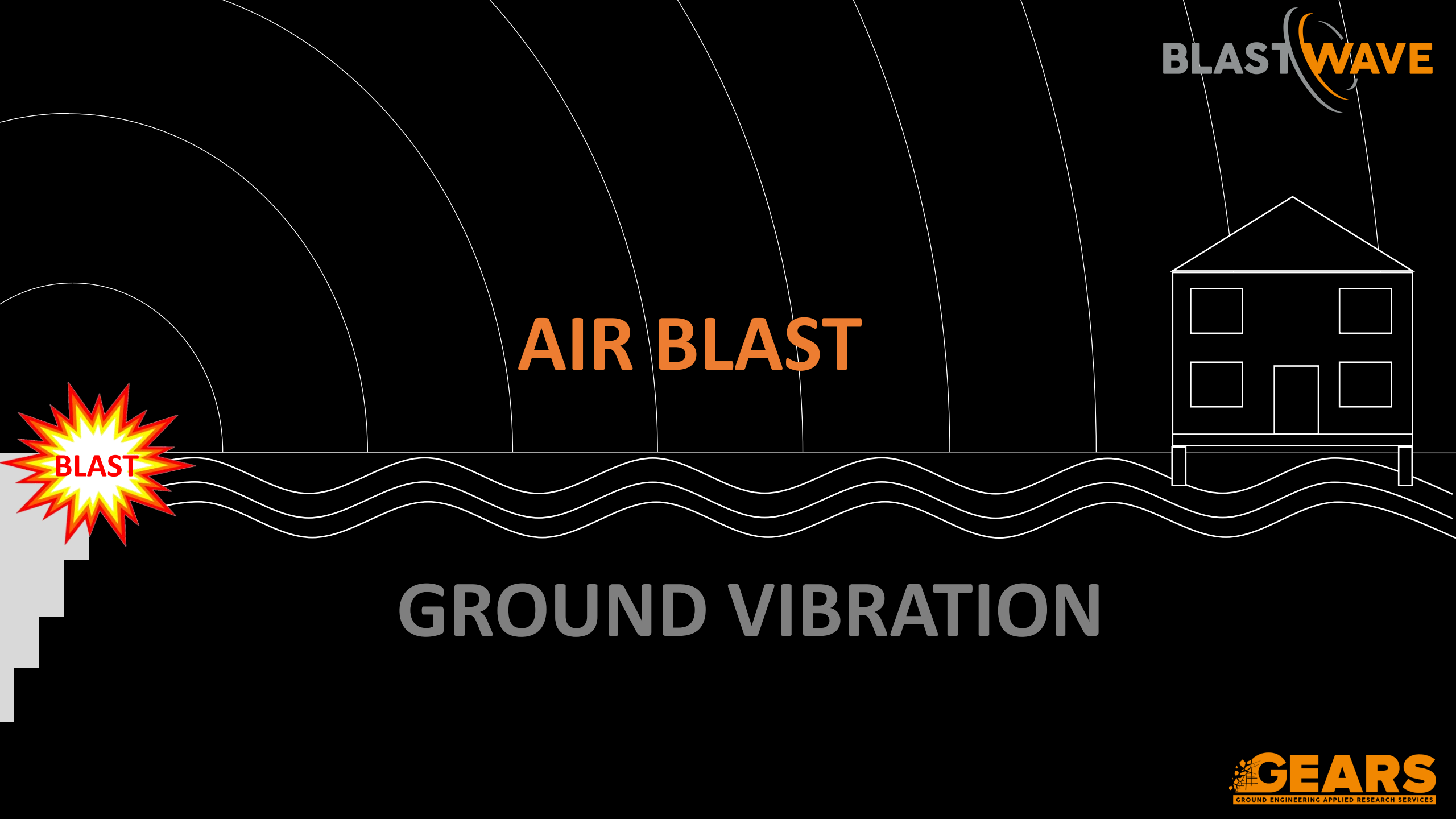
New guidance to be published to ensure correct understanding and practise for:

- Blast impact monitoring
- Blast design practises to reduce environmental impacts

Launch an impartial informative website for the general public

BLASTWAVE

PLANNING POLICY | **BLAST DAMAGE** | NUISANCE IMPACT | CO_2 EMISSIONS | BLAST MONITORING | BLAST OPTIMISATION | EIA

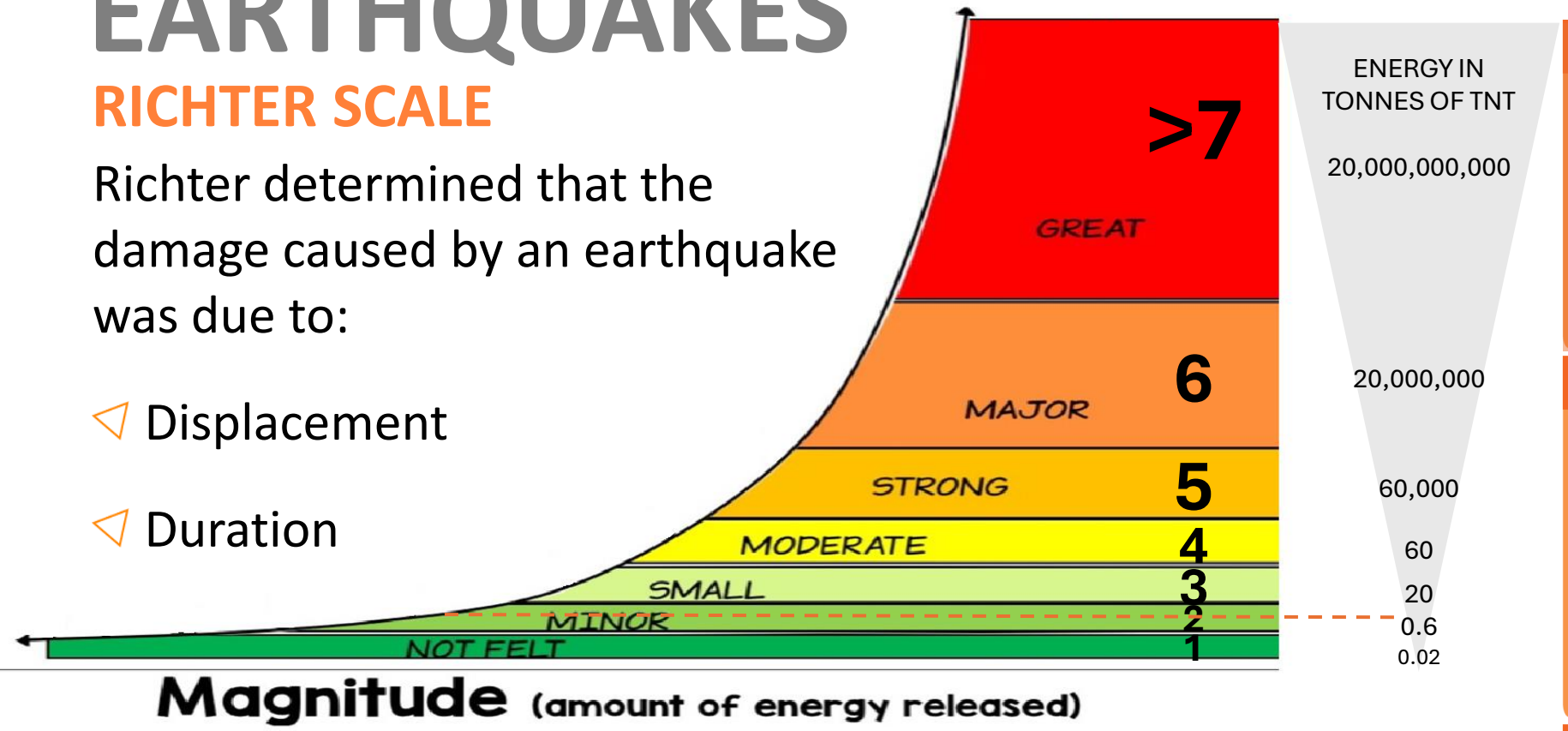

BLAST WAVE
AIR BLAST
BLAST
GROUND VIBRATION
GEARS
GROUND ENGINEERING APPLIED RESEARCH SERVICES

EARTHQUAKES

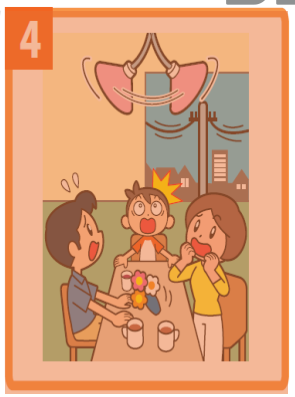
RICHTER SCALE

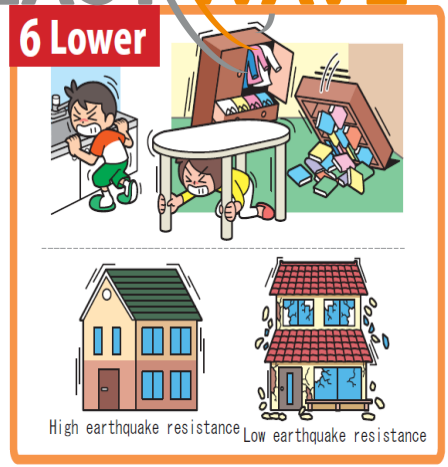
Richter determined that the damage caused by an earthquake was due to:

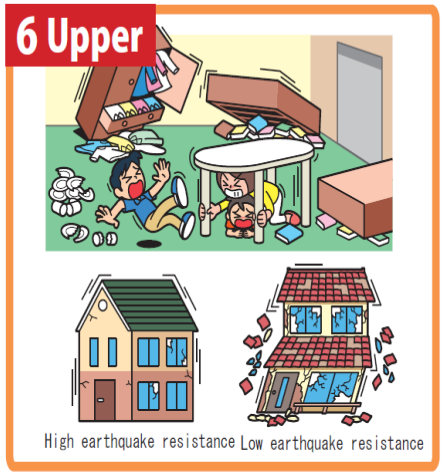
- Displacement
- Duration

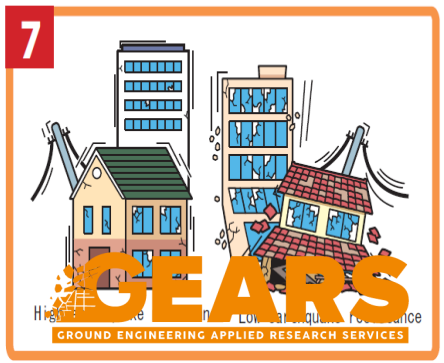


BLAST WAVE





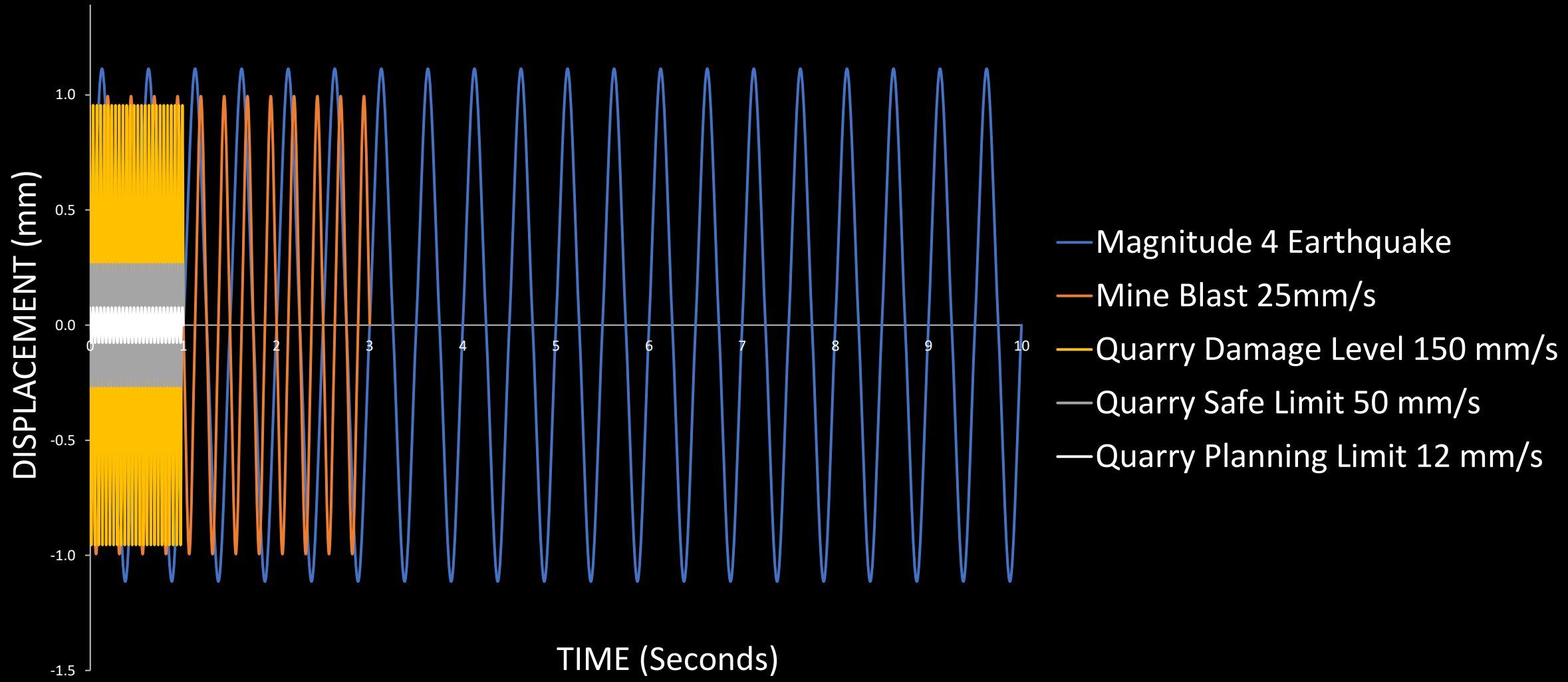




GEARS
GROUND ENGINEERING APPLIED RESEARCH SERVICES

VIBRATION DAMAGE

EARTHQUAKE AND BLAST WAVES

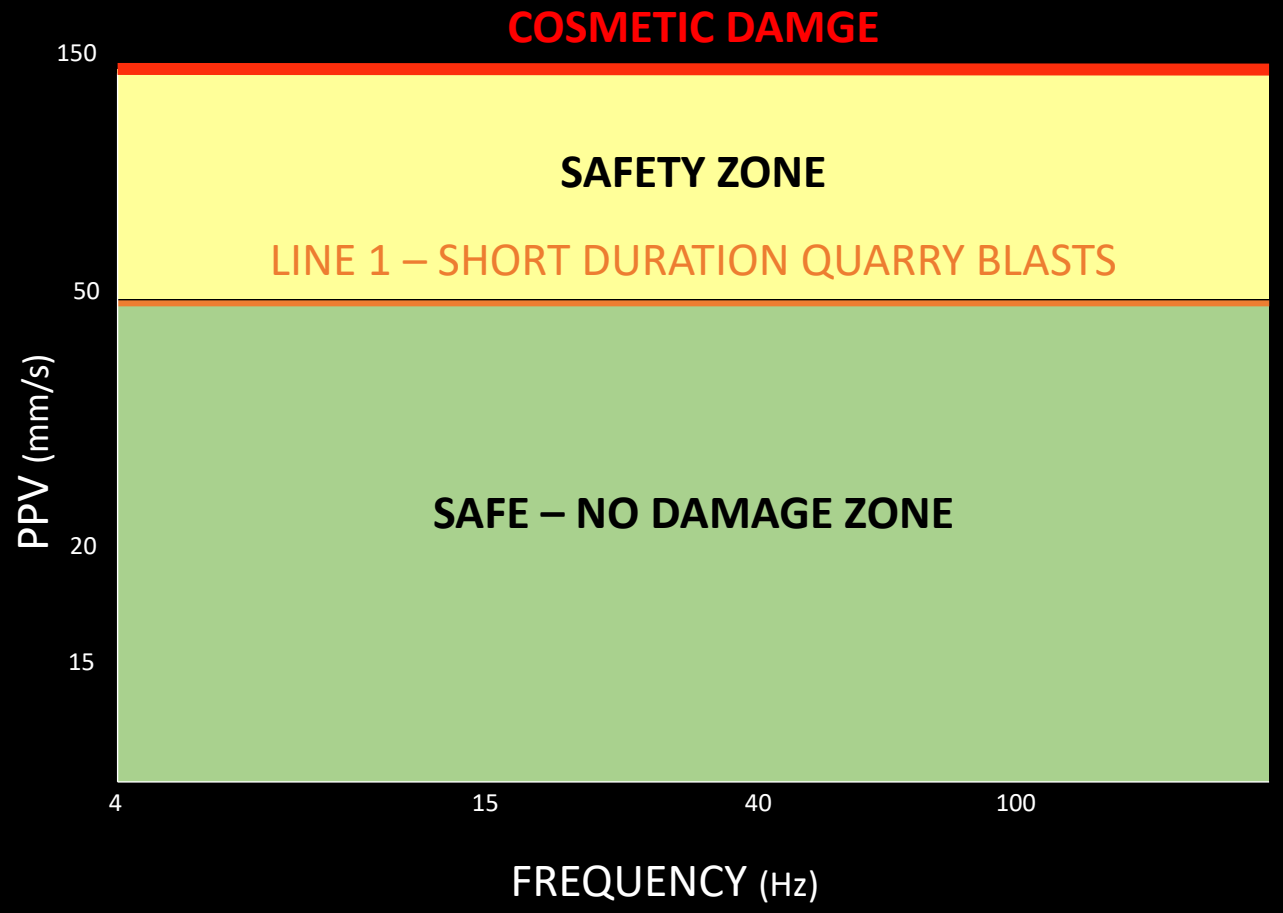


VIBRATION DAMAGE

THE EMPIRICAL QUARRY BLAST DATA - USBM 656 - 1971

The USBM determined the following for a quarry blast:

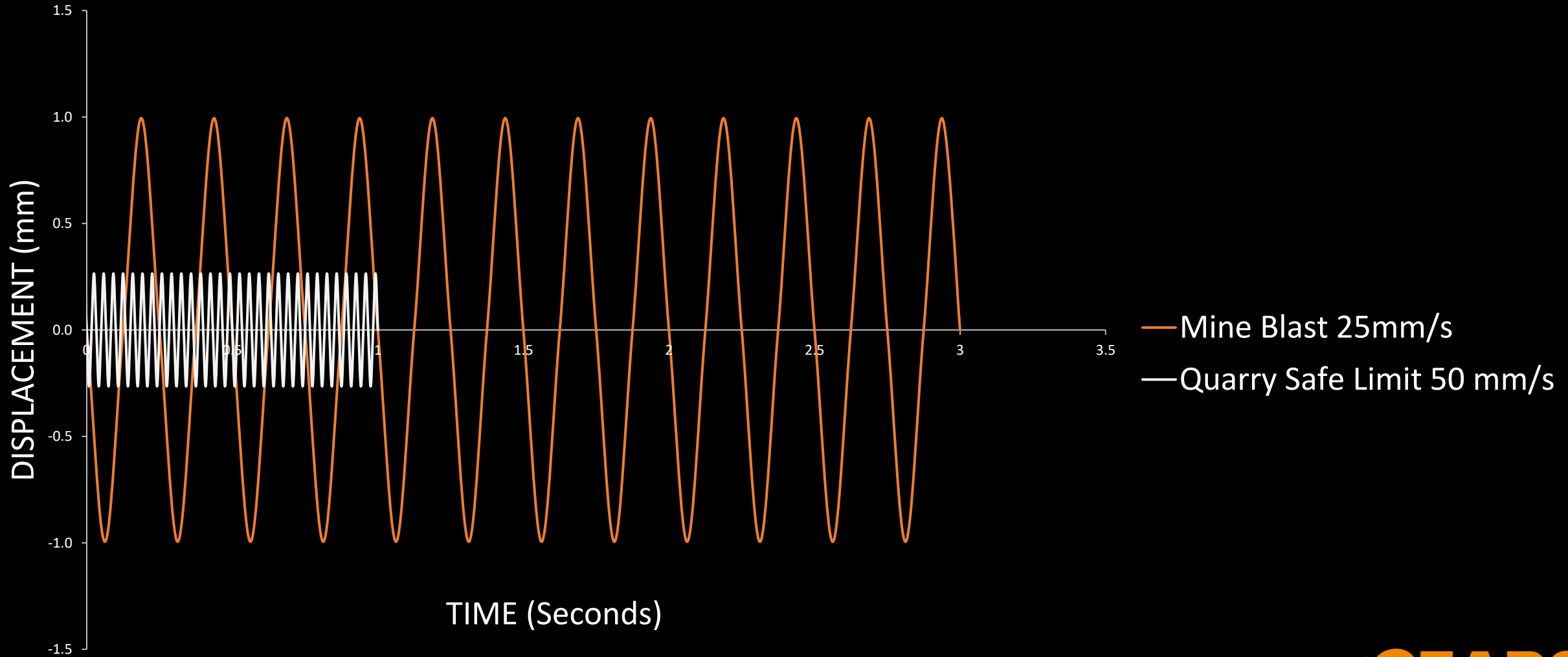
- PPV of 150 mm/s can cause cosmetic damage
- No damage PPV limit 50mm/s
- No cases of damage below 50 mm/s*



** Based on several extensive literature reviews*

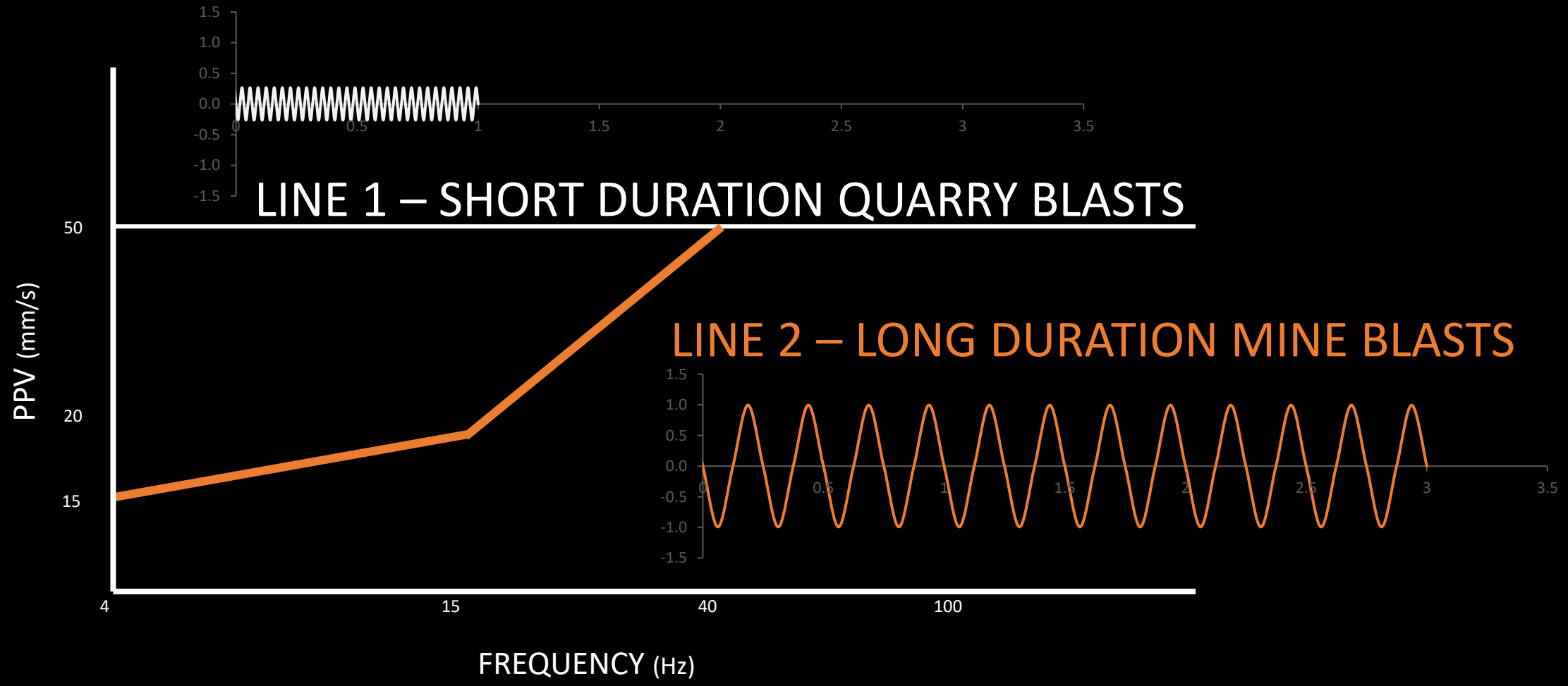
VIBRATION DAMAGE

QUARRY AND MINING BLAST WAVES



VIBRATION DAMAGE

THE EMPIRICAL DATA - USBM BULLETIN RI 8507 - 1987



VIBRATION DAMAGE

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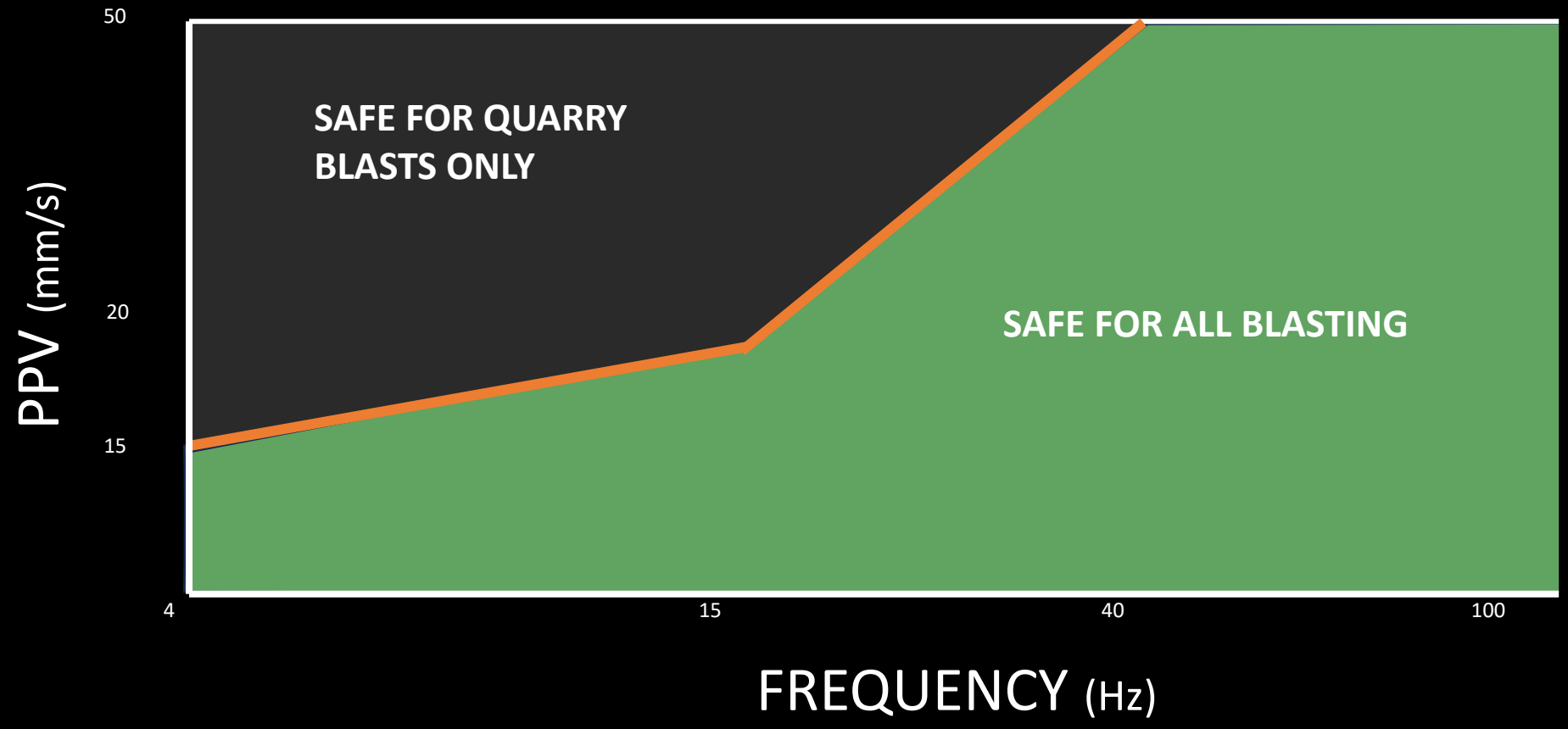
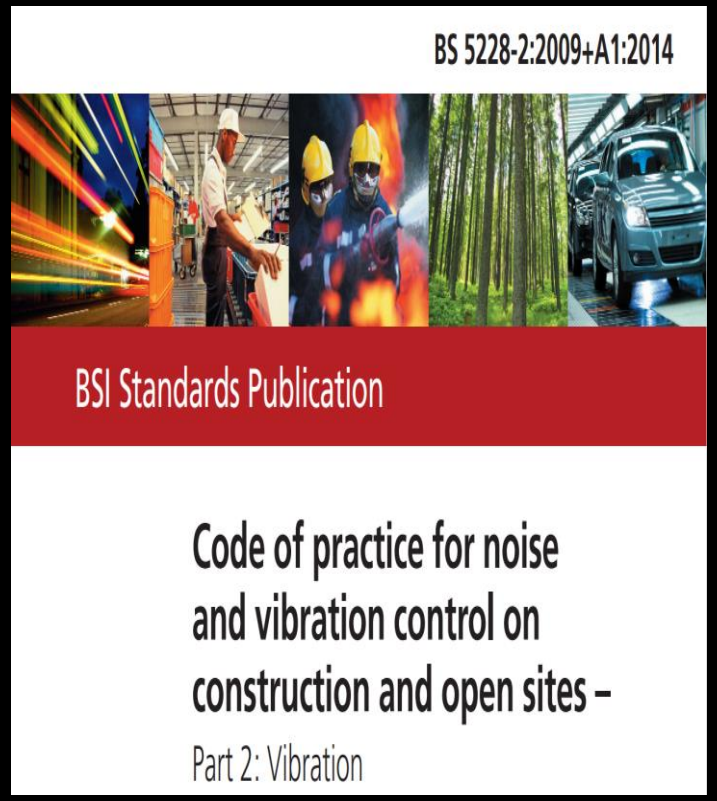
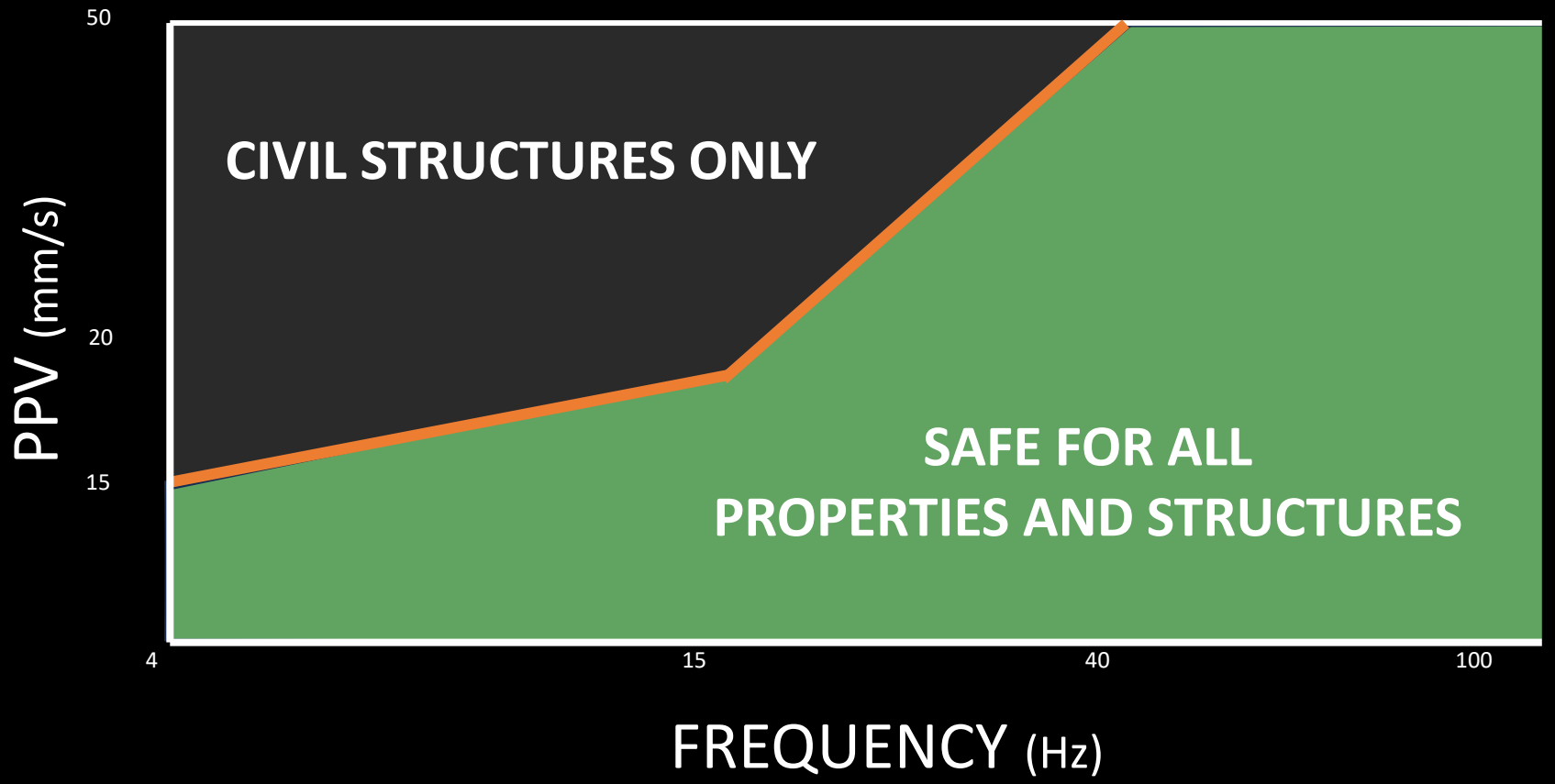


BRITISH STANDARD

DAMAGE THRESHOLDS





ENGINEERING ASSESSMENT

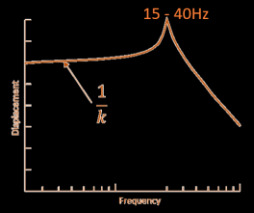
BLAST WAVE

THE IMPORTANCE OF NATURAL FREQUENCY

LIGHT MATERIALS STIFFNESS CONTROLLED

Hooke's Law

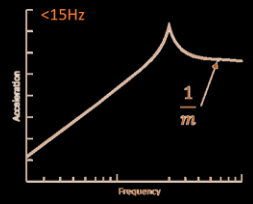
Force = Stiffness × Extension

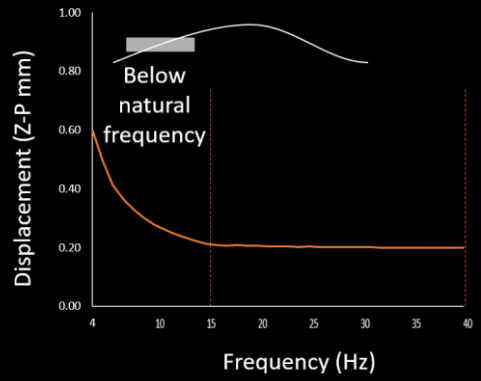


STRUCTURES & HEAVY MATERIALS MASS CONTROLLED

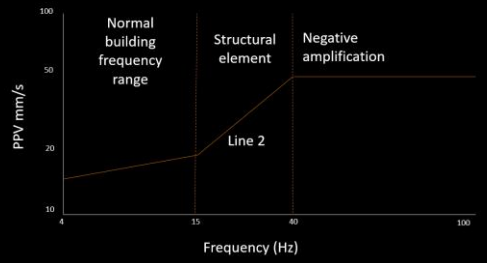
Newton's Second Law

Force = Mass × Acceleration

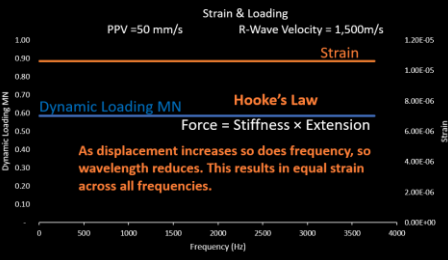




Materials with a low stiffness and so high natural frequency – *Lightweight materials*



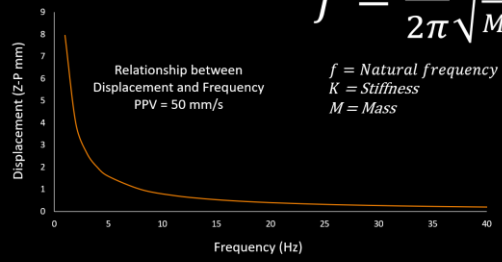
Structures and materials with significant mass and so low natural frequency



LOW MASS MATERIALS

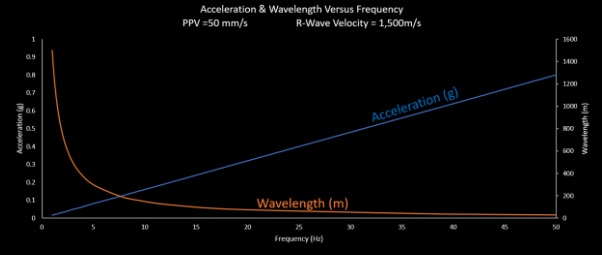
$$f = \frac{1}{2\pi}\sqrt{\frac{K}{M}}$$ K - GOVERNS

$f = Natural\ frequency$
$K = Stiffness$
$M = Mass$



SAFE BLAST PPV LIMIT FOR QUARRY BLASTING IS 50 mm/s

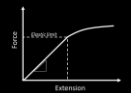
Structures and materials with significant mass and so low natural frequency



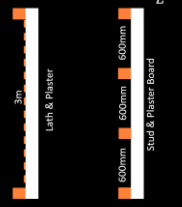
Hooke's Law

- Strain in a solid is **directly proportional** to the applied stress **within the elastic limit** of that solid

Force = Stiffness × Extension



Stiffness (k) $k = \frac{EA}{L}$



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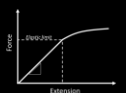

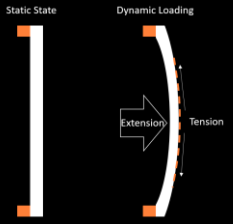

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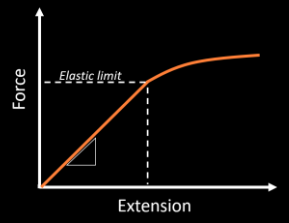

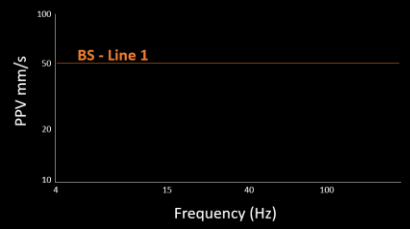

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$f = Natural\ frequency$
$K = Stiffness$
$M = Mass$

GEARS
GROUND ENGINEERING APPLIED RESEARCH SERVICES

BLAST DAMAGE STUDY

BLAST DAMAGE STUDY

- PPV up to 150 mm/s

MONITORING AT BUILDING

- Structural defects
- Cosmetic defects
- Ground vibration
- Structural response

BLAST DAMAGE STUDY

BLAST EXPERT 1

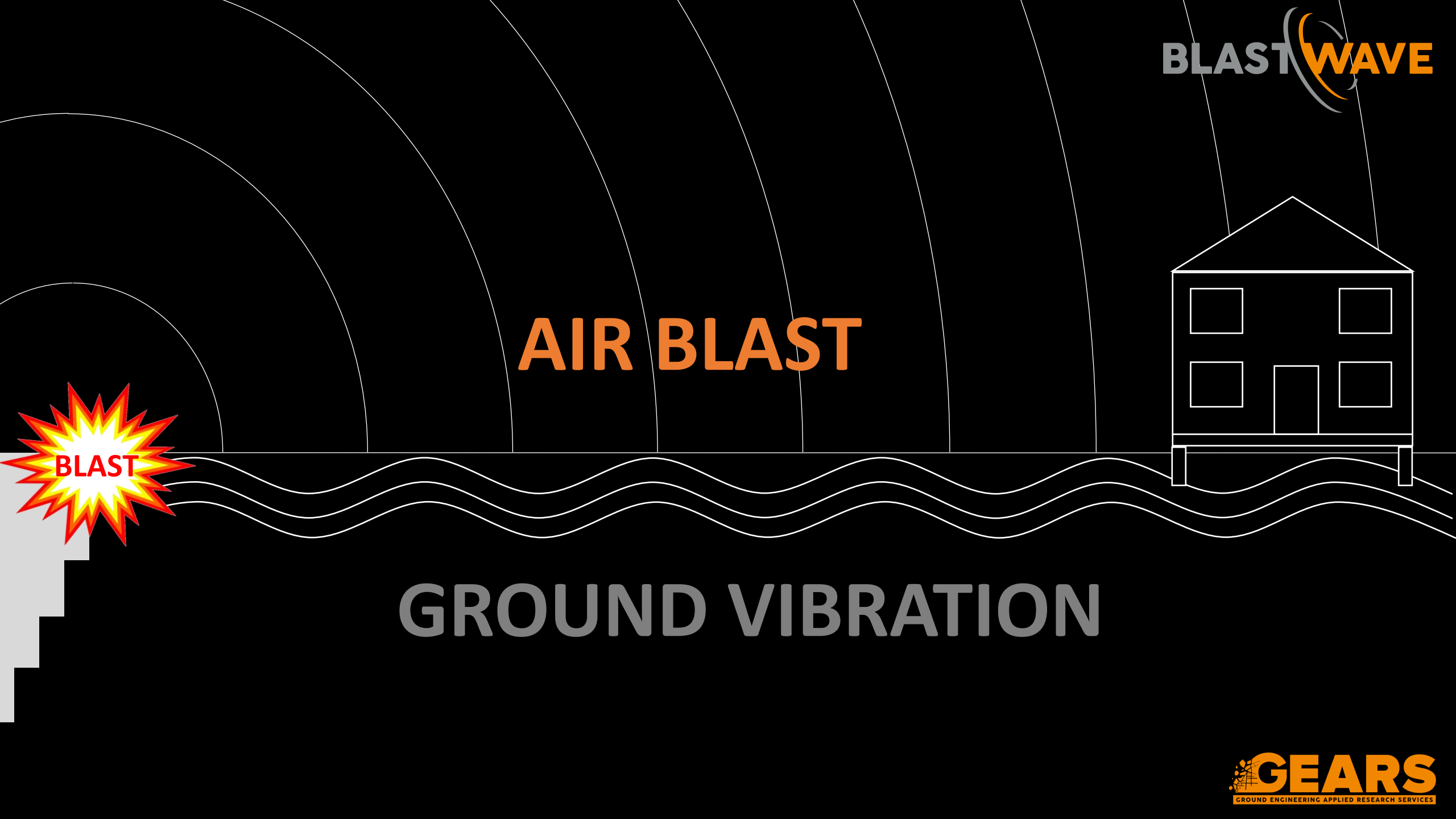
Plaster will crack at a PPV of 5 mm/s, as proven by the British Standard

BLAST EXPERT 2

The building is going to fall down

THANKS...


TARMAC
A CRH COMPANY
BLAST WAVE
VIBRATION DAMAGE TEST BLAST
03/07/23 - PPV 150 mm/s
GEARS
GROUND ENGINEERING APPLIED RESEARCH SERVICES
M2M
MINE TO MILL


BLAST WAVE
AIR BLAST
BLAST
GROUND VIBRATION
GEARS
GROUND ENGINEERING APPLIED RESEARCH SERVICES

DAMAGE LEVEL

AIR OVERPRESSURE (AOP)

Pressure (Pa)	SPL (dbL)	Wind Speed (mph)	Beauford Scale	Impact
633	150	72	Force 12 - Hurricane	Windows start to break
200	140	40	Force 7 - Near Gale	Safe No Damage Level
63	130	23	Force 4 - Moderate Breeze	Maximum likely quarry blast air overpressure at the quarry boundary
20	120	13	Force 3 - Gentle Breeze	Typical maximum pressure outside of the quarry
6.3	110	7	Force 2 - Light Breeze	Building internal structure rattles – Perceptible
2	100	4	Force 1 - Light Air	Barely perceptible

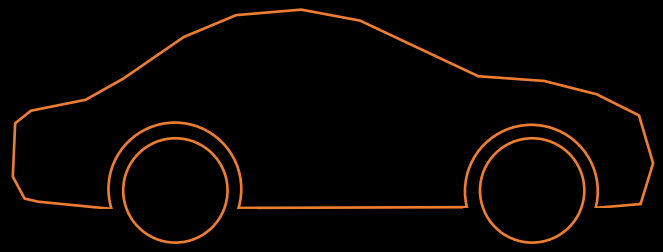
- There is no risk of a normal quarry blast causing any damage to property as the air overpressure is typically up to a Force 4 Moderate Breeze
- This is 10 times lower than the forced needed to cause damage

BLASTWAVE

PLANNING POLICY | BLAST DAMAGE | **NUISANCE IMPACT** | CO_2 EMISSIONS | BLAST MONITORING | BLAST OPTIMISATION | EIA

HUMAN RESPONSE

PPV IS A MAX VELOCITY - IT HAS VERY LIMITED VALUE WHEN DETERMINING NUISANCE



VELOCITY

DISPLACEMENT

ACCELERATION

HUMAN RESPONSE

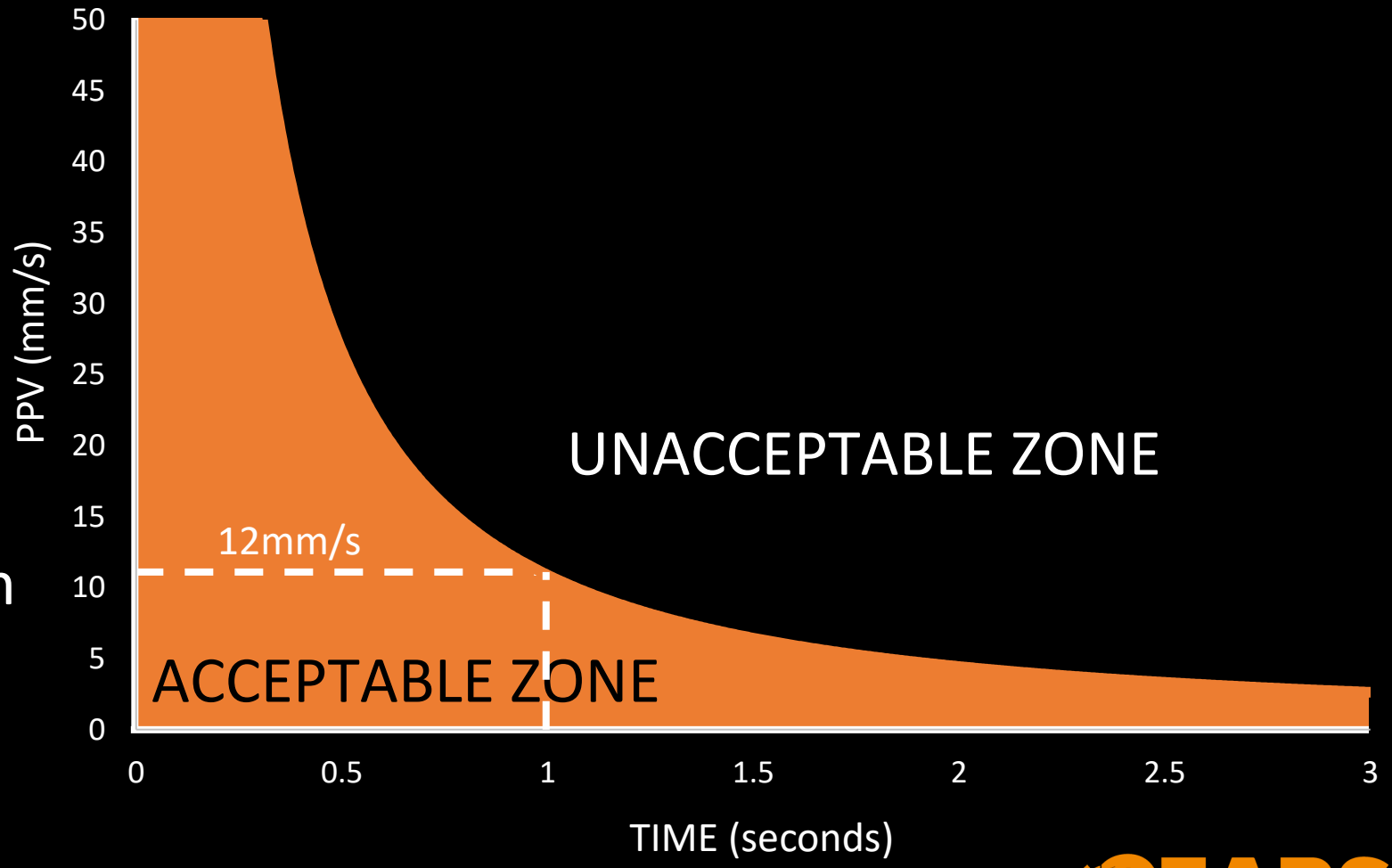
EARTHQUAKES

Modified Mercalli Intensity	Earthquake Magnitude	Perceived Shaking	Peak Ground Velocity mm/s (Worden et al 2012)	Modified Mercalli Intensity Description
I	<3	NOT FELT	0.2	Not felt
II	3.25	WEAK	5.1	Felt only by a few people at rest, especially on upper floors of buildings
III	3.75	WEAK	12	Felt quite noticeably by people indoors, especially on upper floors of buildings
IV	4.25	LIGHT	14	Felt indoors by many, outdoors by few during the day. At night, some are awakened.
V	4.75	MODERATE	47	Felt by nearly everyone, many awakened
VI	5.25	STRONG	96	Felt by all, and many are frightened

HUMAN RESPONSE

USBM 8507 from 1980

- In 1980 the USBM recommended an acceptable PPV nuisance level of 12mm/s for a quarry blast
- This was based on a 1 second blast wave duration
- The UK adopted the same nuisance PPV level



PLANNING CONTROLS

NUISANCE LIMITS

PAN 50 Annex D: Controlling the Environmental Effects of Surface Mineral Workings Annex D: The Control of Blasting at Surface Mineral Workings February 2000

- 12 mm/s recommended limit
- Average levels not below 6mm/s

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

Minerals Planning Policy (Wales) Minerals Technical Advice Note (Wales) 1: AGGREGATES

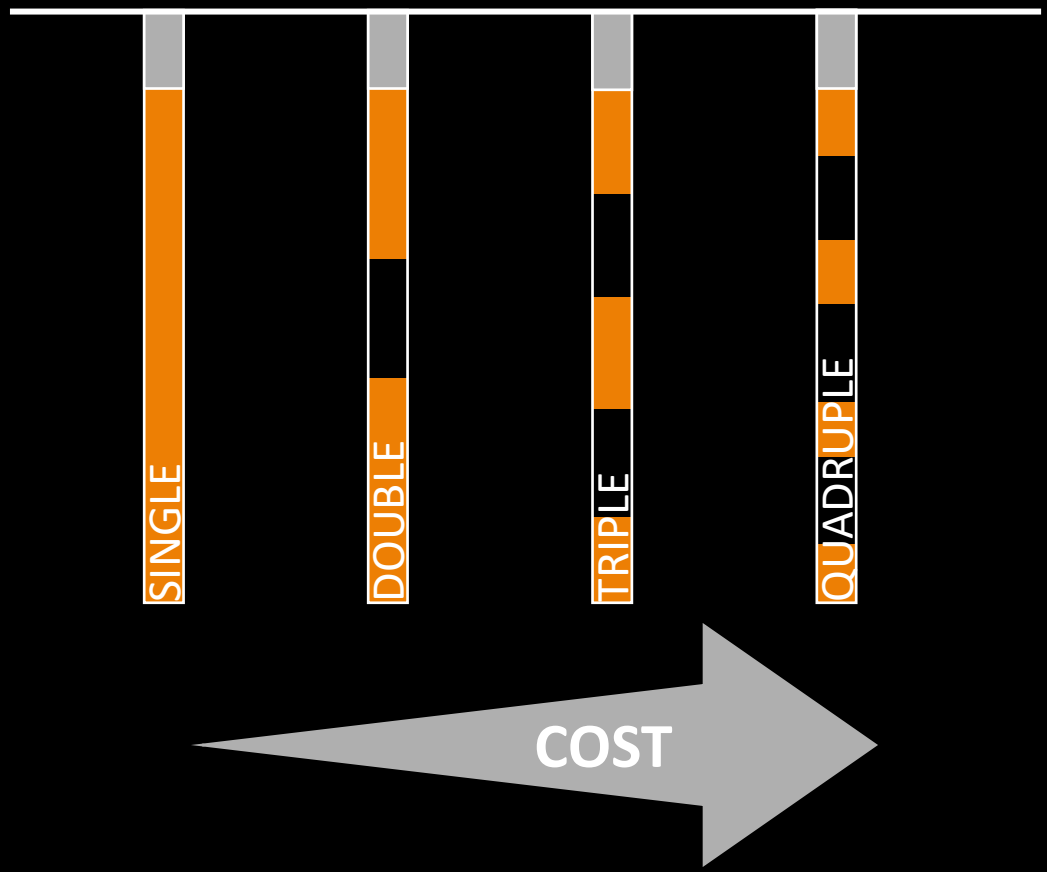
- 6 mm/s recommend limit

** Limits quoted at 95%*

LOW PPV LIMITS

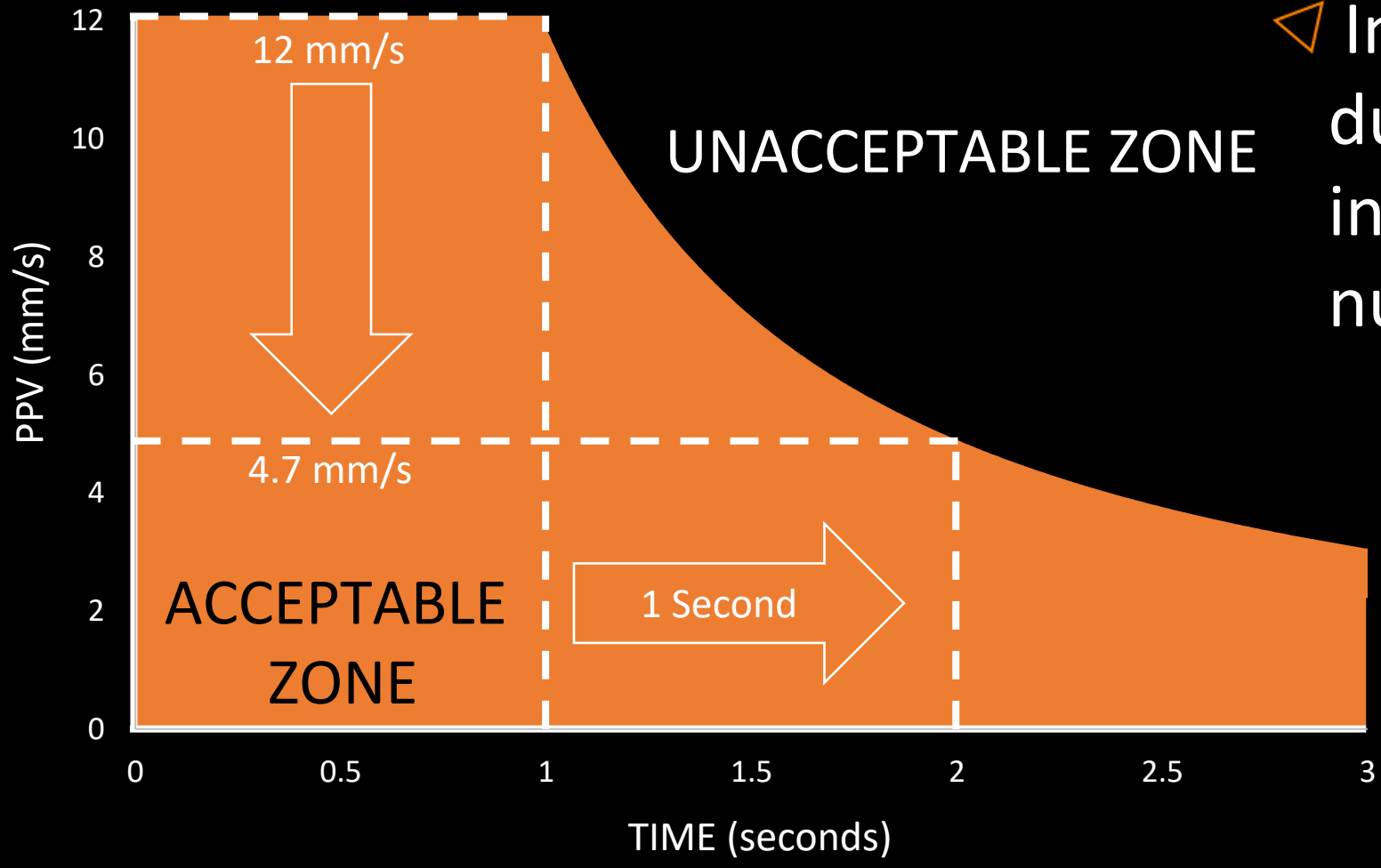
DECKING

- Standard method of reducing the PPV is to deck (split up) the shot hole
- Each deck basically halves the PPV
- But decking will:
  - Increases the duration
  - Reduce the blast waves frequency
  - Reduce the fragmentation



LOW PPV LIMITS

CONSEQUENCES



- Increasing the duration significantly increases the nuisance level

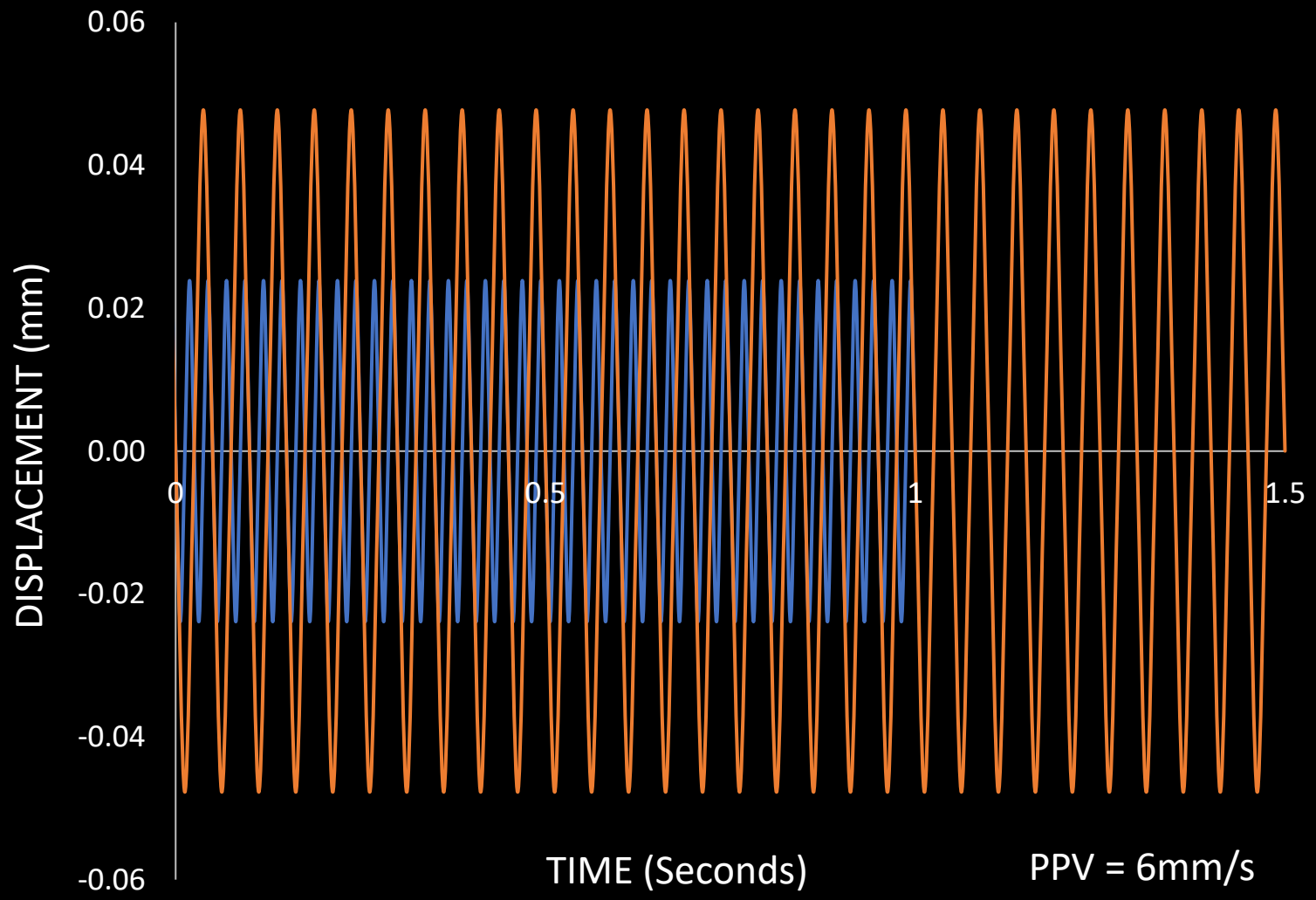
LOW PPV LIMITS

CONSEQUENCES

- Decreasing the frequency increases the displacement

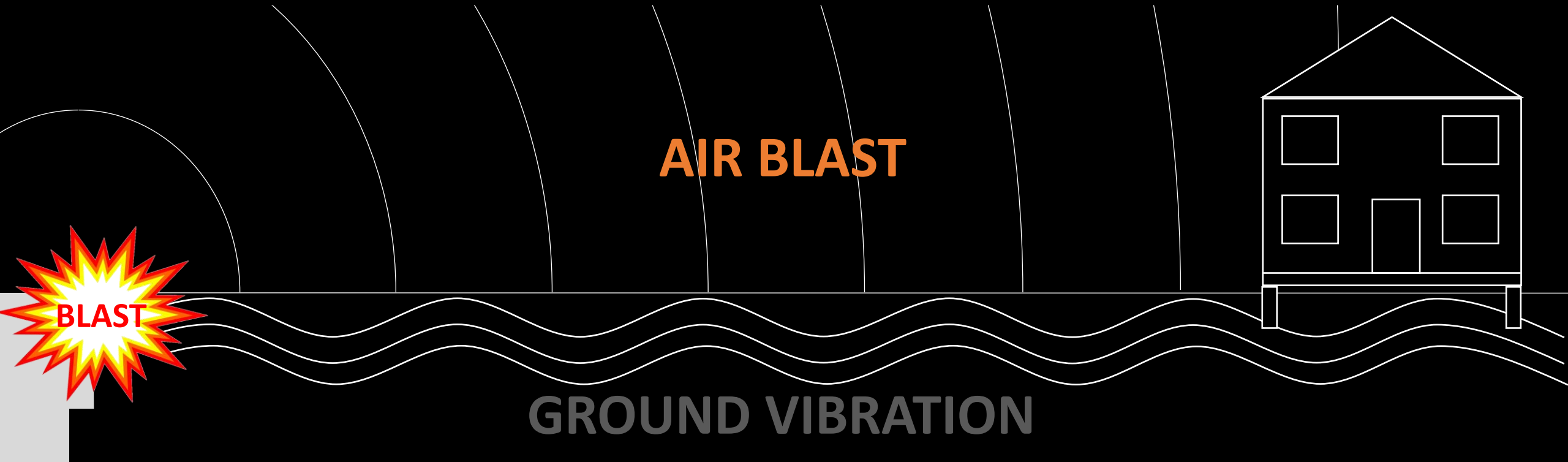
Quarry blast without decking

Quarry with decking



BLAST WAVE

BLAST DAMAGE | **NUISANCE IMPACT** | CO_2 EMISSIONS | BLAST MONITORING | BLAST OPTIMISATION | EIA | PLANNING POLICY



NUISANCE IMPACT

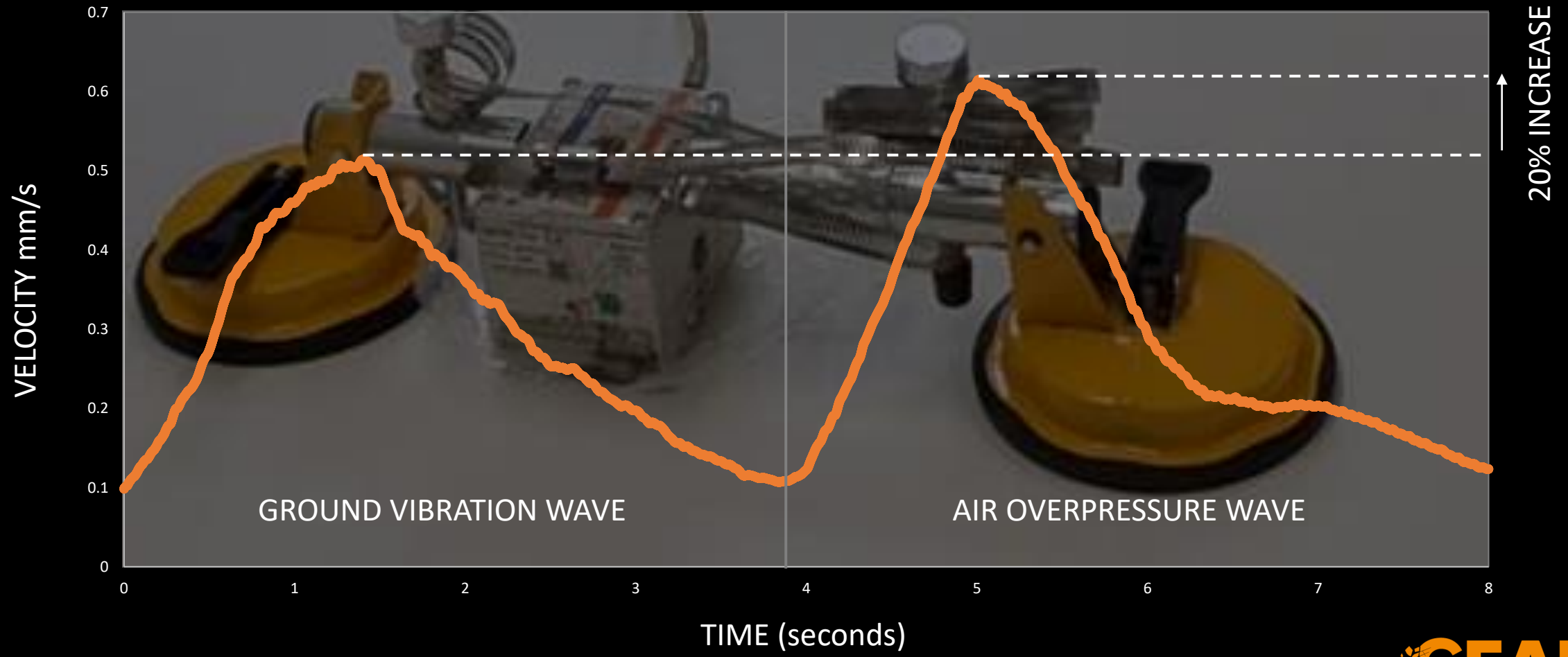
AIR OVERPRESSURE (AOP)

Pressure (Pa)	SPL (dbL)	Wind Speed (mph)	Beauford Scale	Impact
633	150	72	Force 12 - Hurricane	Windows start to break
200	140	40	Force 7 - Near Gale	No Damage Level
63	130	23	Force 4 - Moderate Breeze	Maximum likely quarry blast air overpressure (in quarry) and likely complaint if frequency is moderate (>3 Hz)
20	120	13	Force 3 - Gentle Breeze	Typical maximum pressure outside of the quarry boundary & likely complaint if the frequency is high (>4 Hz)
6.3	110	7	Force 2 - Light Breeze	Building internal structure rattles – Perceptible
2	100	4	Force 1 - Light Air	Barely perceptible

- Complaint threshold is dependent on the climatic conditions and the building's natural frequency

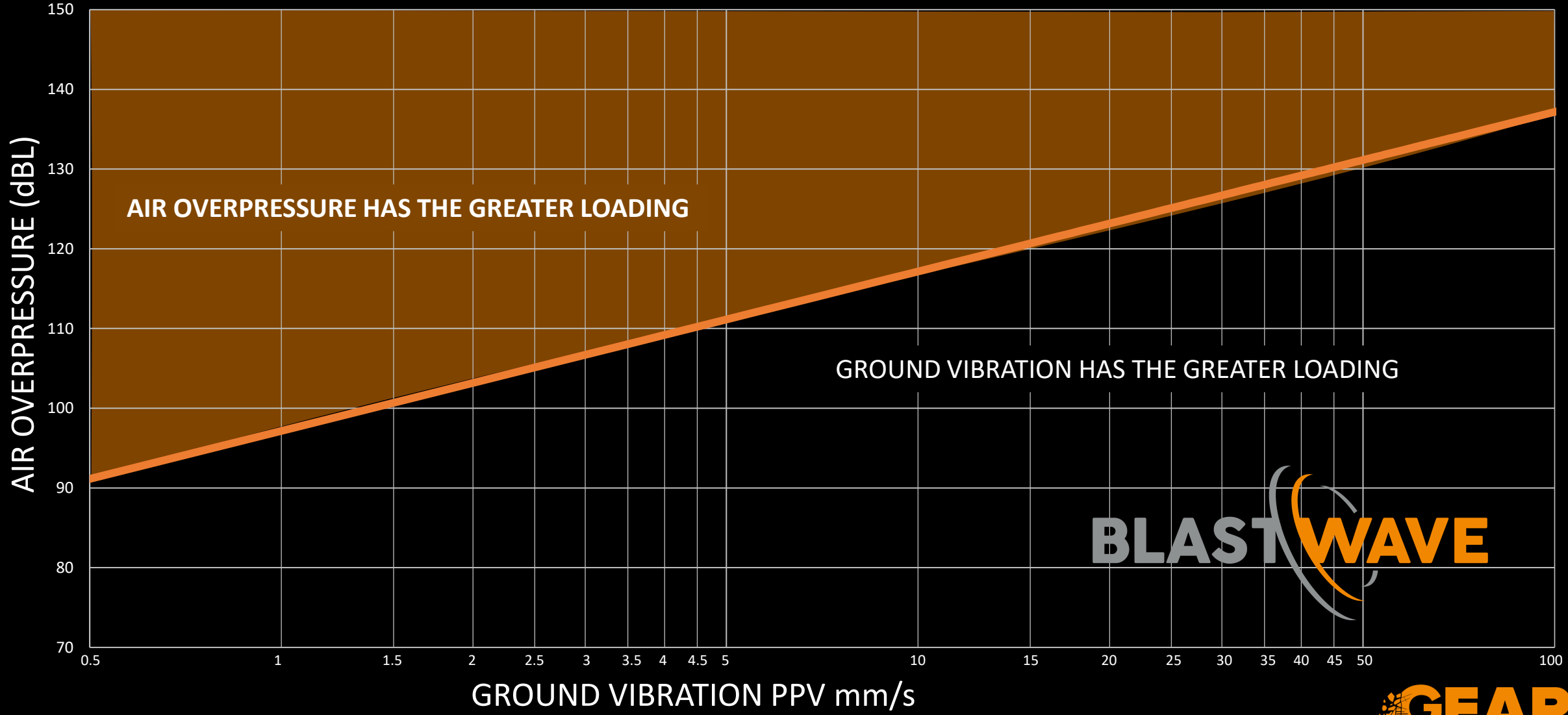
NUISANCE IMPACT

GROUND VIBRATION VERSUS AIR OVERPRESSURE WAVE



NUISANCE IMPACT

GROUND VIBRATION VERSUS AIR OVERPRESSURE WAVE



EXAMPLE PROPERTY – NOTE ASSESSMENT IS PROPERTY SPECIFIC

NUISANCE IMPACT

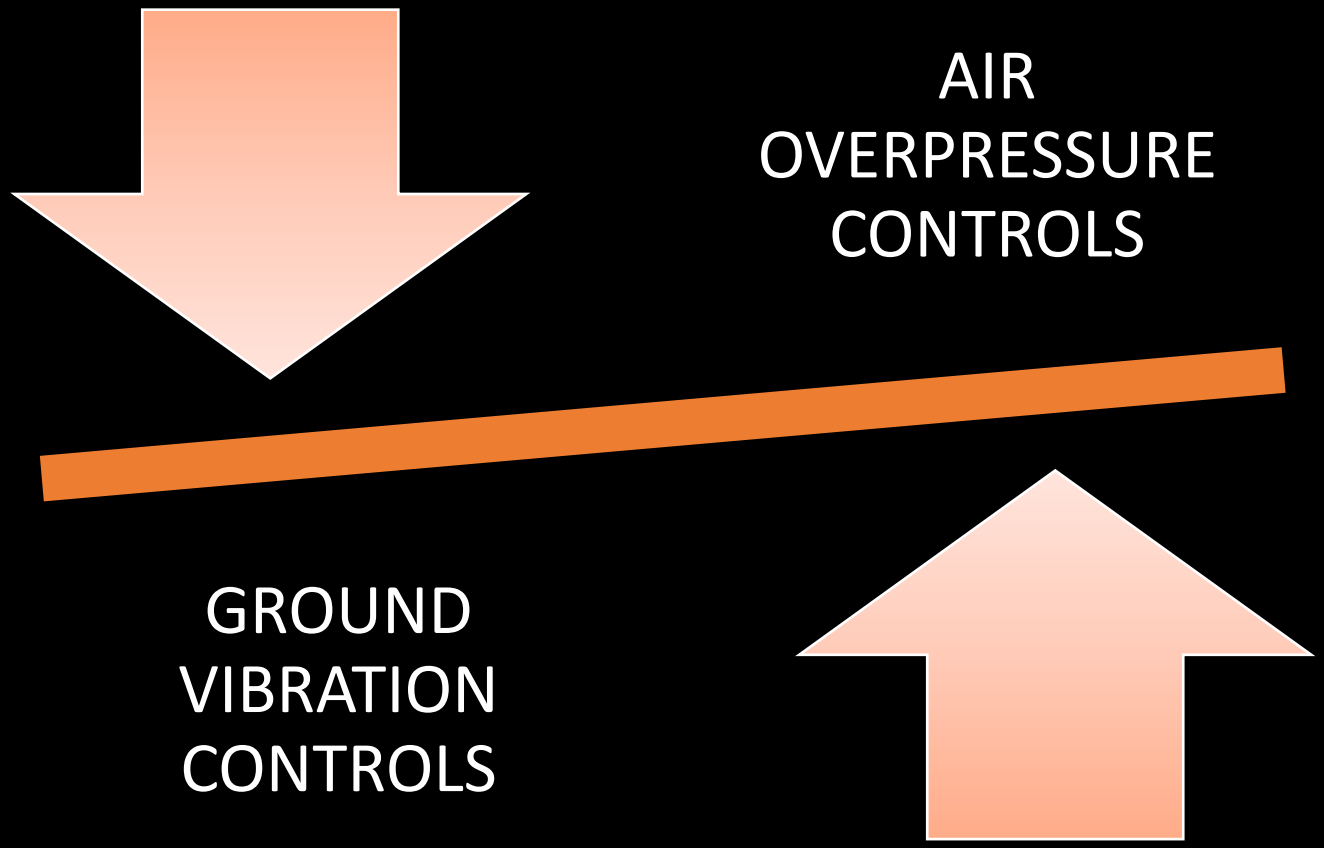
GROUND VIBRATION VERSUS AIR OVERPRESSURE WAVE

DECKING WILL:

- REDUCE THE PPV

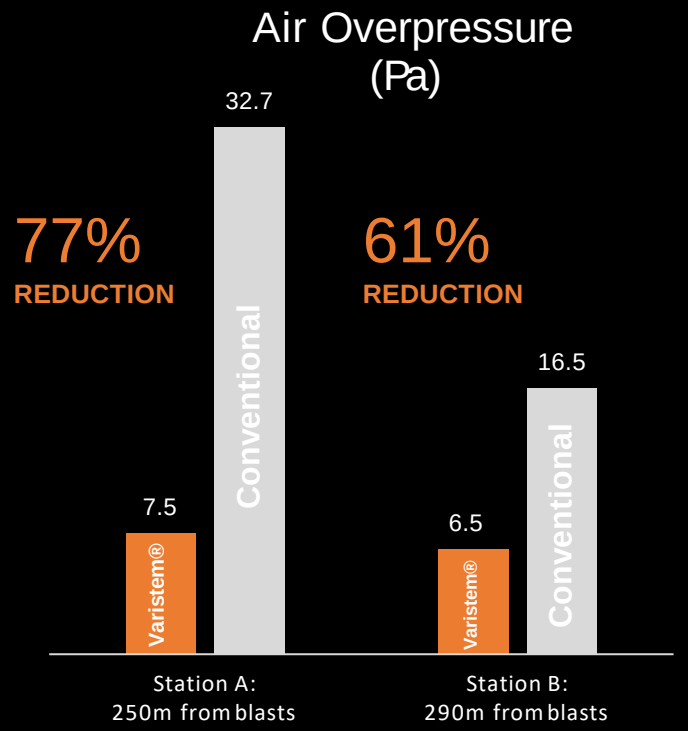
BUT

- INCREASE THE AIR OVERPRESSURE



NUISANCE IMPACT - AOP

STEMMING PLUGS



Average Pressure readings (kPa) for two pressure meter stations. Stations recorded pre-and post Varistem® Blasts

BLASTWAVE

PLANNING POLICY

BLAST DAMAGE

NUISANCE IMPACT

CO_2 EMISSIONS

BLAST MONITORING

BLAST OPTIMISATION

EIA

BLAST DOWN CO_2

IQ The Institute of Quarrying

CO_2 INEFFICIENCIES

77,680t CO_2

FROM UK HARDROCK QUARRIES PER ANNUM

IQ
The Institute of Quarrying

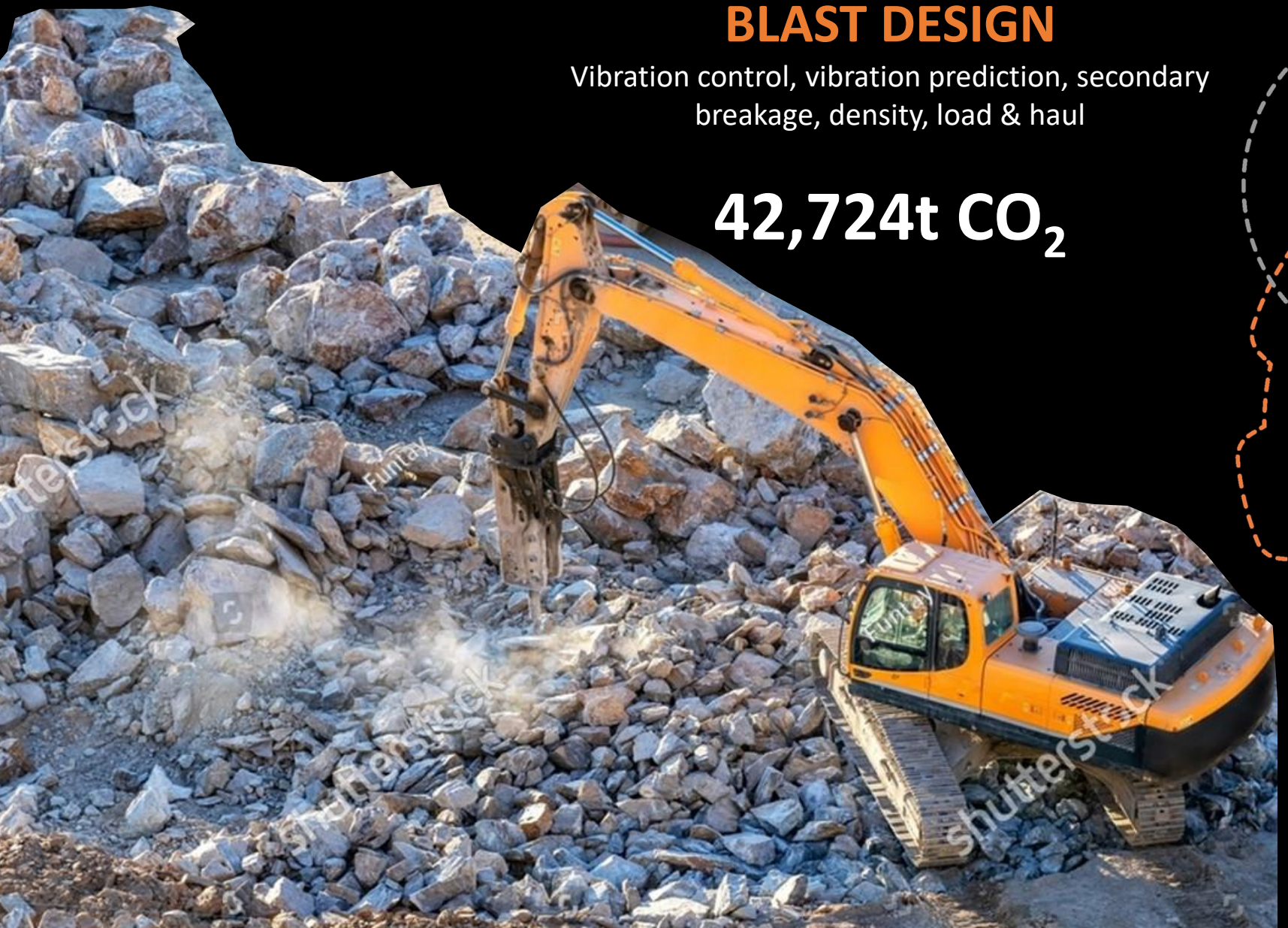
BLAST DOWN CO_2

TARMAC
A CRH COMPANY

BLAST DESIGN

Vibration control, vibration prediction, secondary breakage, density, load & haul

42,724t CO_2



FROM UK HARDROCK QUARRIES PER ANNUM

IQ
The Institute of Quarrying

The Emerald Challenge
WINNER
2023

BLAST WAVE

FRAG MAP

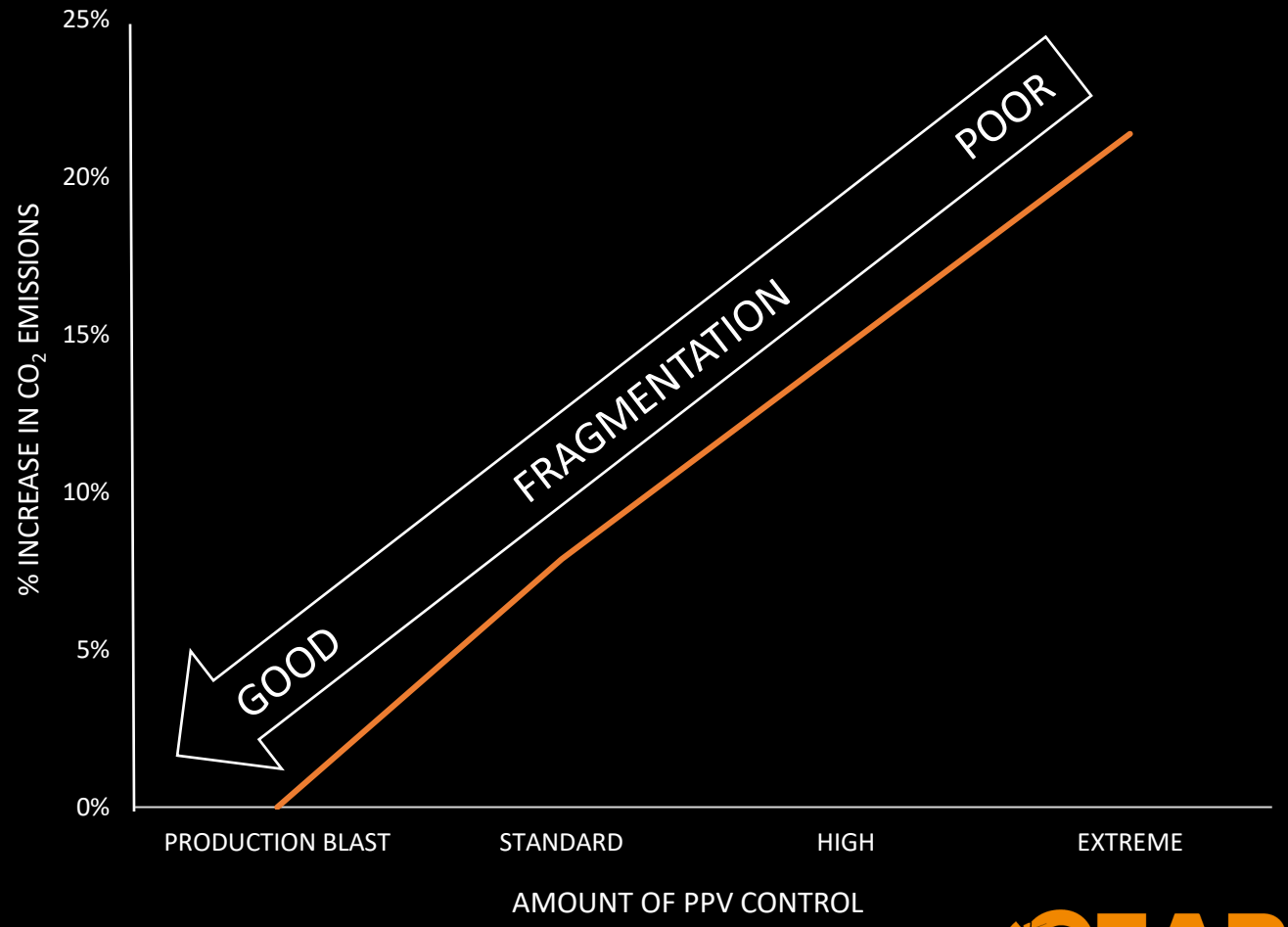
GEARS
GROUND ENGINEERING APPLIED RESEARCH SERVICES

CO_2 EMISSIONS

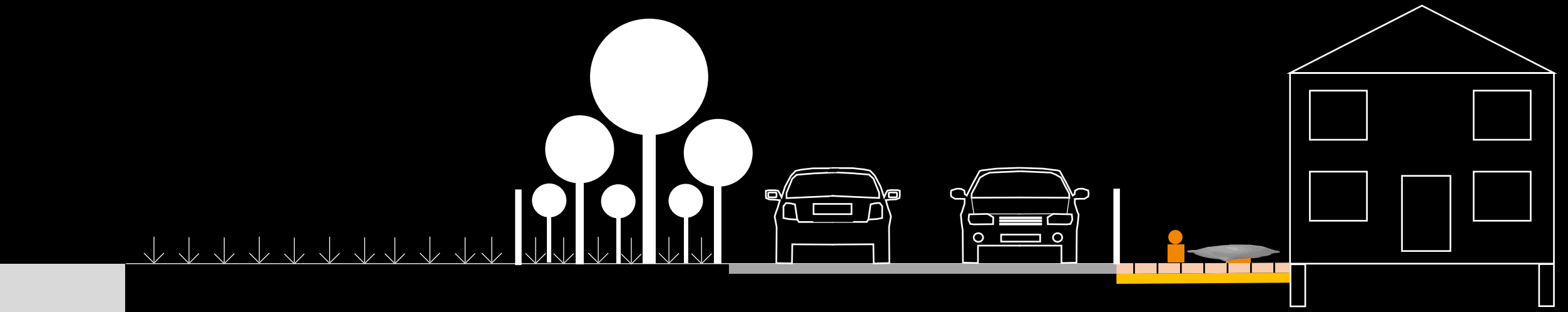
IMPACT OF PPV CONTROL ON CO_2 EMISSIONS

FOR THE EXTREME CASE:

- Due to poor fragmentation CO_2 emissions can increase by up to 21% (1Kg/t)
- When full M2M costs are accounted for this is costing the operator up to an extra £2/t



BLAST MONITORING



STANDARD PRACTICE FOR BLASTING MONITORING IS RESULTING IN:

- 25% overestimation of PPV
- 70% overestimation of air overpressure
- Which is causing around a 50% prediction error

TARMAC
A CRH COMPANY

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BLAST WAVE

PLANNING POLICY | BLAST DAMAGE | NUISANCE IMPACT | CO_2 EMISSIONS | BLAST MONITORING | BLAST OPTIMISATION | EIA

- Safe damage PPV limit = 50 mm/s
- Nuisance PPV limit = 12 mm/s *(but trial a new measure)*
- Scheme of monitoring and improvement (Air Blast)

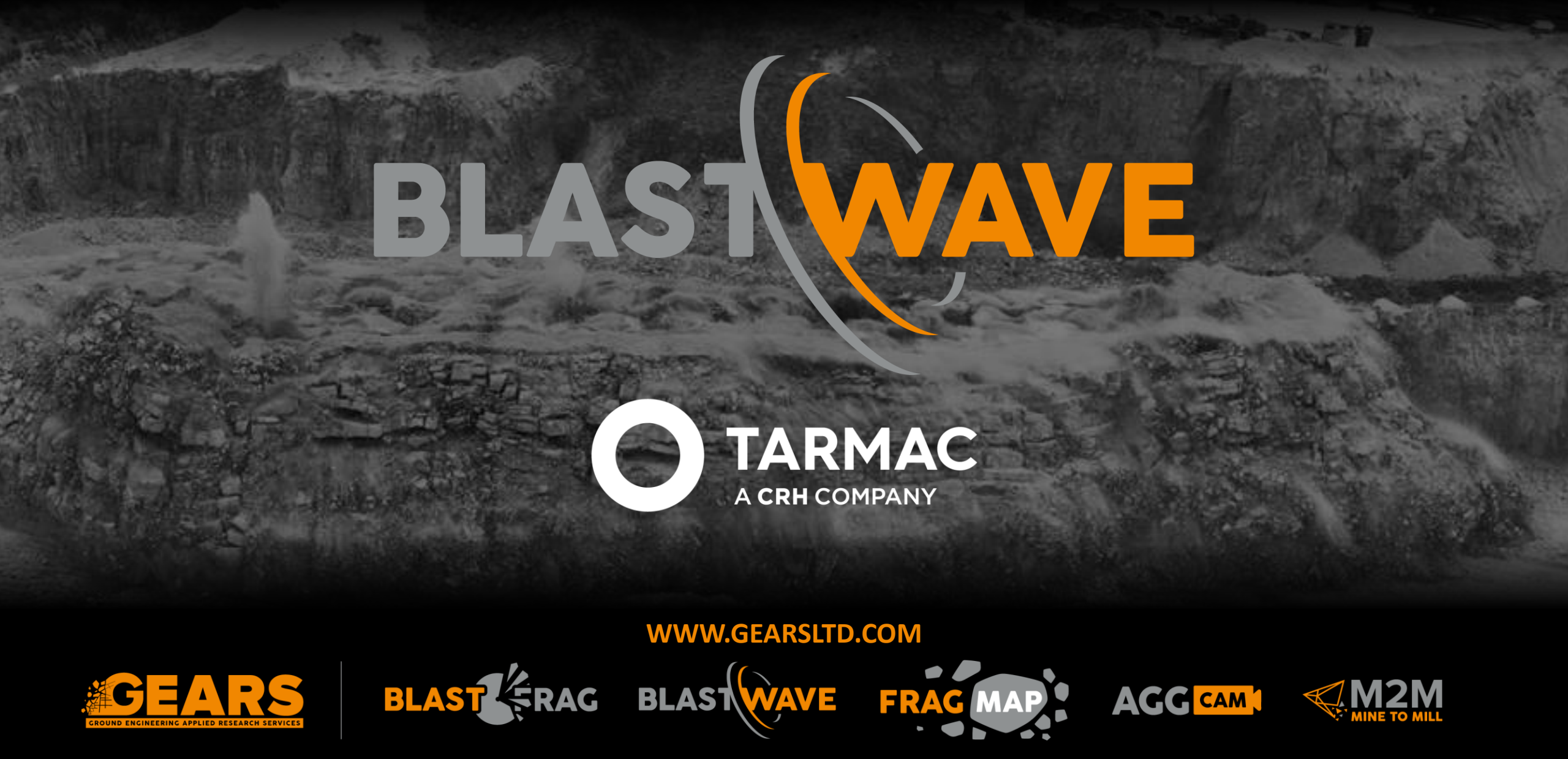
} PAN 50

- New guidance
- Informative website

RTPI
Royal Town Planning Institute

WE'RE HAVING A BLAST

mpa
essential materials
sustainable solutions



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BLAST FRAG | BLAST WAVE | FRAG MAP | AGG CAM | M2M MINE TO MILL