DEVELOPMENT OF ISO-RESPONSE CURVE FOR THE BLAST RESISTANT WALL

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Abstract: *Iso-Response curve is used for finding out the damage level of the structure under blast loading. This curves can be formed by using analytical method. There is no need of performing experiments of blast for knowing the damage criteria which in terms saves time and proofs to be economical. In this paper different ranges of pressure and impulse is considered. The non-linear dynamic analysis is done considering the time stepping method in that Newmark's linear acceleration method is considered. By using this method for every pressure – impulse range the maximum displacement and ductility factor is found out. By considering these two factors the Iso-Response curve is developed in the MINITAB Software. Also the comparison between the 200mm and 300mm thick wall is done considering two parameters that is maximum displacement and ductility factor. The different zones of Iso-response curve is also mentioned and damage criteria is also shown in terms of ductility factor.*

Key Words: *Iso-Response curve, Blast Loading, Damage Level, Non-Linear Dynamic Analysis, Newmark's Linear Acceleration Method, MINITAB Software, Ductility Factor.*

1. INTRODUCTION:

Iso-Response curves are the curves which represent the damage level of the structure. As per IS: 4991-1968, no Codal provisions are provided for the Iso –Response Curve. Development of these curves are having its own importance because every time experiment is not possible and its cost is very high. So it is uneconomical to perform the experiment. So we are referring Iso-Response curve.

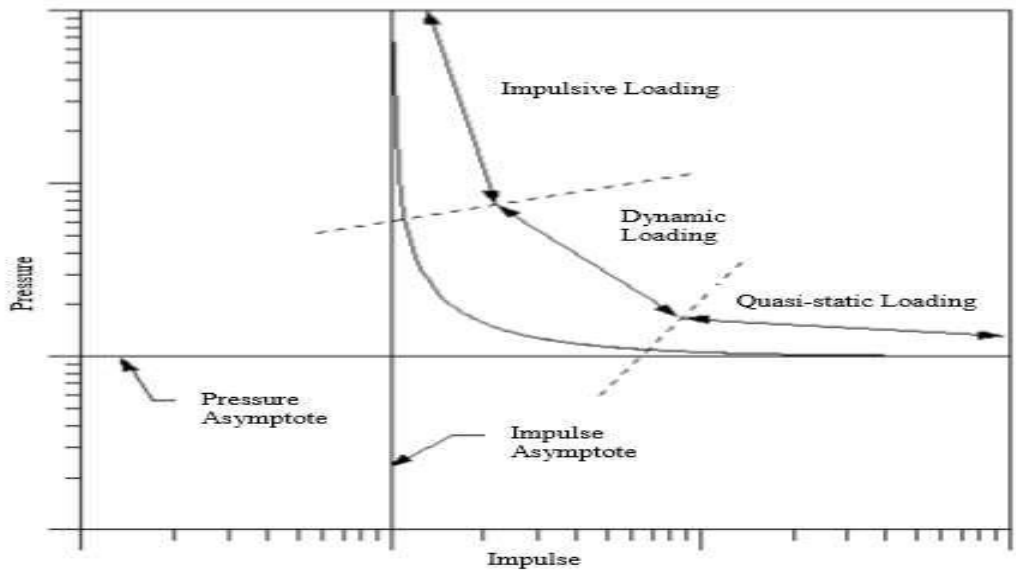


Fig.1: Pressure-Impulse Curve

Dynamic Loading Regime:

Mays and Smith (1995) suggest that a certain load falls in one of the three regimes depending on the product between the natural circular frequency of the system ω and the load duration td as indicated below:

Impulsive loading ω td < 0.4

Dynamic 0.4 < ω td < 40

Quasi-static loading ω td > 40

2. PROCEDURE OF DEVELOPMENT OF THE ISO-RESPONSE CURVE:

For developing the Iso-Response curve the first stage is to fix the ordinate for the pressure and the impulse range. In this the x – ordinate is considered to be the impulsive range and the y – ordinate is showing the pressure range as shown in fig2. Now, the ordinates are fixed then the range for the pressure is considered as 2 psi to 30 psi and the impulse range is considered to be 10kpa-sec to 10000 kPa-sec.

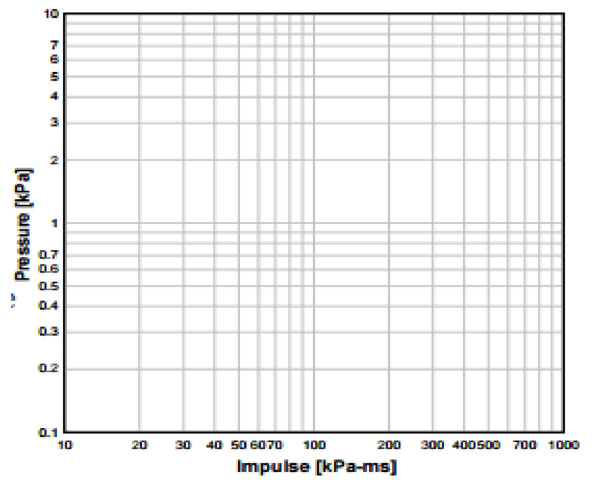


Fig.2: Pressure-Impulse Axis

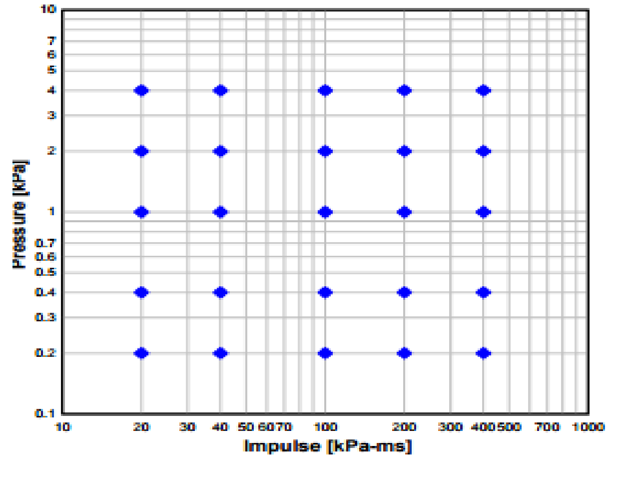
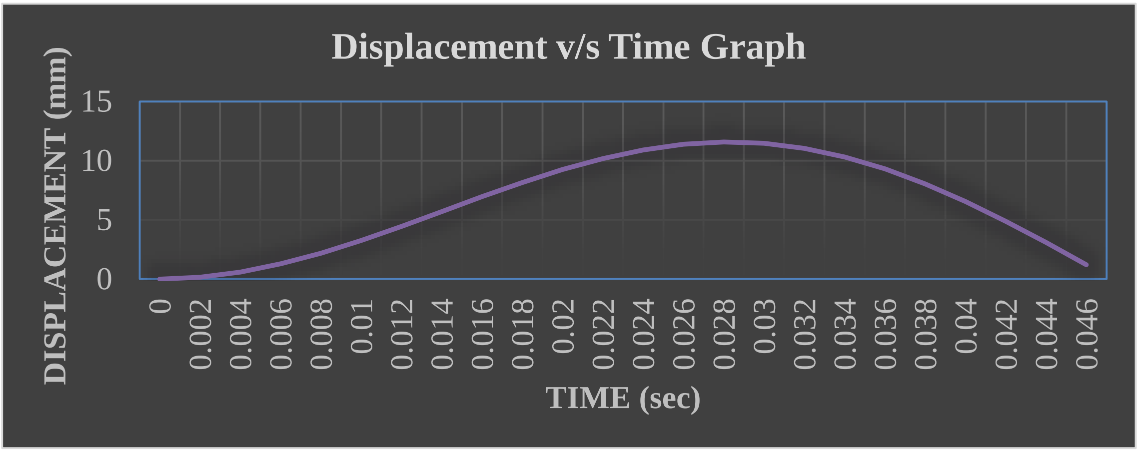


Fig.3: Grid Formation

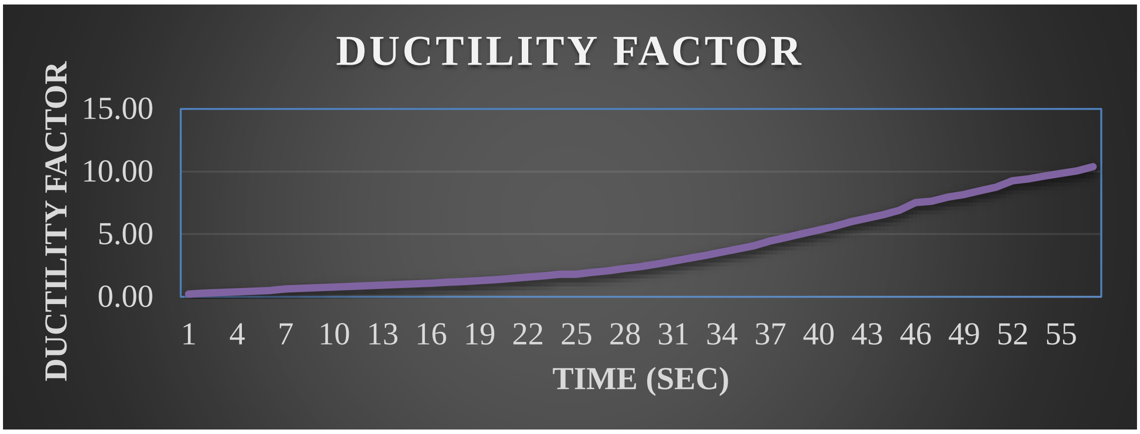
Second stage for developing the Iso-Response curve is the grid formation as shown in fig.3. In this for every stage of pressure and impulse the maximum response and ductility factor is considered.

For every stage of pressure and impulse we find the blast duration td and based on that duration yield displacement and maximum displacement is found. On the basis of this the contour is plotted using MINITAB Software – 2015 for the 200 mm and 300 mm thick wall considering maximum response and ductility factor. One example is shown below regarding the maximum displacement value that is considered for this study. Consider the pressure 10 psi and impulse 1000 psi and the duration of blast that we have get from this pressure – impulse range is 0.286 sec for the 300 mm thick RC wall. The displacement – time graph is plotted below from that we get the maximum displacement value as shown in graph 1.



Graph 1: Variation of Displacement with respect to Time

From the above graph the maximum displacement value that we have get is 11.58 mm. considering the same procedure for every pressure – impulse value the numerical integration method is done and then the maximum value of displacement is find. Similarly for the same pressure and impulse range the ductility factor is found which is shown below in graph 2.



Graph 2: Variation of Ductility Factor with Respect to Time

Now following the above procedure all the values of pressure, impulse, maximum response and ductility factor is putted in MINITAB Software for the contour formation so that we get the impulsive range, dynamic range and quasi-static range for the 300 mm and 200 mm thick wall.

3. RESULTS:

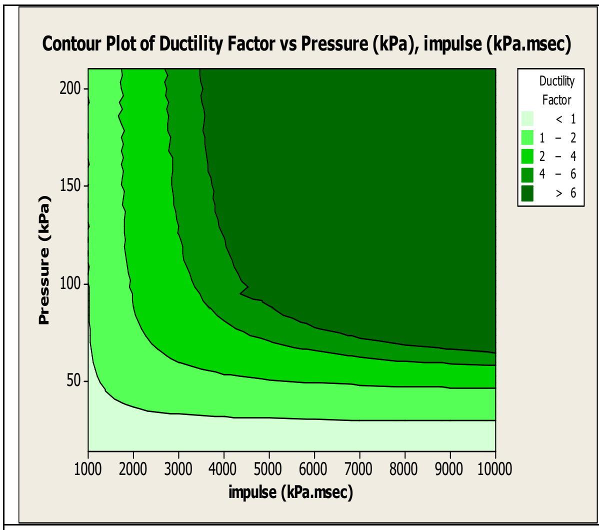


Fig.3: Iso-Response Curve for 200mm Thick Wall Considering Ductility Factor.

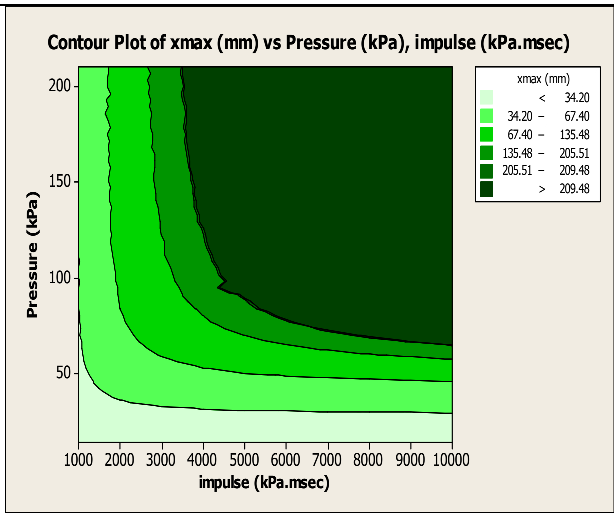


Fig.4: Iso-Response Curve for 200mm Thick Wall Considering Maximum Response.

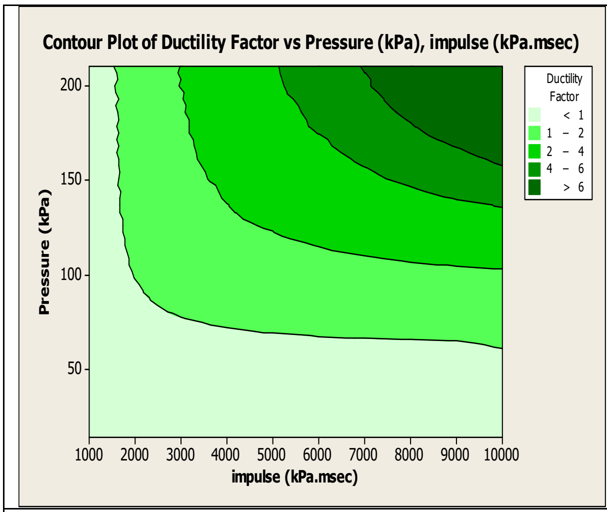


Fig.5: Iso-Response Curve for 300mm Thick Wall Considering Ductility Factor

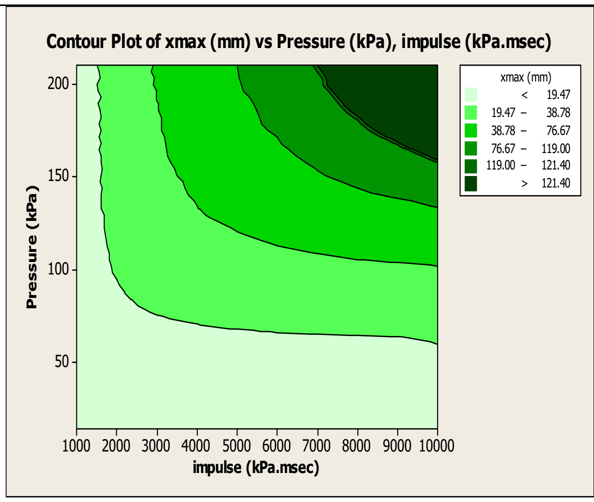


Fig.6: Iso-Response Curve for 300mm Thick Wall Considering Maximum Response

Table 1: Different Ranges for the 300mm and 200mm Thick Wall Considering Ductility Factor

Ductility Factor	*Type of Damage*	*PI Range for 300 mm Thick wall (psi-kpa.sec)*	*PI Range for 200 mm Thick wall (psi-kpa.sec)*	*Maximum Displacement Range for 300 mm Thick wall (mm)*	*Maximum Displacement Range for 200mm Thick wall (mm)*
μ < 1	Negligible Damage	2 – 10 to 13.5 - 2000	2 – 10 to 14 – 1000	0 to 19.47	0 to 34.2
1≤ μ < 2	Light Damage	14 – 2000 to 28 – 3000	14.5 - 1000 to 12 - 2000	19.95 to 38.78	34.38 to 67.40
2 ≤μ < 4	Moderate Damage	28.5 – 3000 to 24.5 - 6000	12.5 – 2000 to 17.5 - 3000	40.24 to 76.67	68.69 to 135.48
4 ≤μ < 6	Substantial Damage	25 – 6000 to 29.5 – 7000	18 – 3000 to 17.5 - 4000	80.28 to 119	138.03 to 205.51
μ ≥ 6	High Damage	30 -7000	18 - 4000	≥ 121.40	≥ 209.47

Table 2: Different Types of Damage Based on Ductility Factor

Ductility Factor	*Type of Damage*	*Economical Loss*	*Safety Implication*
μ < 1	Negligible Damage	No or negligible repair.	No or negligible injuries.
1≤ μ < 2	Light Damage	Minor repairs are needed without disrupting production.	No or negligible injuries.
2 ≤μ < 4	Moderate Damage	Repairable damage. Production can be resumed after inspection and repair or replacement of equipment.	Minor injuries which can be treated on the spot.
4 ≤μ < 6	Substantial Damage	Damage to the main load bearing system is reparable but major equipment is lost. Serious disruption to production.	Some injuries which require medical attention.
μ ≥ 6	High Damage	Beyond repair, probably total loss.	Multiple injuries, life threatening situation probably some fatality.

4. DISCUSSION:

The development of Iso-Response curve is shown above. Iso-response curves have been plotted for the given cases as shown above. Performance of the said building is quantified and categorized with the help of these curves. The Iso-Response curves are plotted for 300 mm and 200 mm thick walls considering maximum displacement and ductility factor. As implicit, 200mm thick wall more prone to damage at low impulse rate of blast wave as compare to the 300 mm thick wall. The working for iso response diagrams indicate that the method and the tool is quite useful for designer to get a feel of the behaviour of the structure and it’s performance with respect to various responses like ductility, displacement and guess the damage levels based on that.

5. CONCLUSION:

Iso-Response curve is a powerful tool. Hence it is recommended that the methodology to access the same should be included in the IS: 4991-1968. Designer will be able to judge the behaviour of the structure and it's various responses like ductility, displacement which affect it's performance. He can then also co-relate them with the damage level, which are expected with the given values of those responses. This can be provided as an appendix to the code.

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