BEHAVIOUR OF SHALLOW FOUNDATION FOR BLAST LOAD ON MULTI-STORY BUILDING FRAME

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ABSTRACT: *A bomb explosion immediately nearby a building can cause catastrophic damage on the building's external and internal structural frames due to which change in soil structure occurs. Studies were conducted on the behavior of soil and structure subjected to blast loads. These studies enhance the understanding on the change in condition of the soil structure due to application of the blast load on the structure.*

A finite element model of soil containing soil base, soil-tet, foundation and a building frame situated above the foundation has been made. The response of column at the contact point of column and foundation and soil at the contact point of foundation and soil-tet due to the application of the blast load has been simulated. The finite element package ***abaqus cae model*** *has been used to model soil and frame with fixed boundary condition and by meshing the soil and building frame.*

For the behavior of shallow foundation on Multi-Story building Frame subjected to blast loading a 3story one bay bare frame has been taken and blast load at a distance of 20m & 30 m of 0.1tnt has been applied on ABAQUS.For simulation, first a dynamic pressure calculated from IS 4991-1968 applied to the front face of the frame and change in the soil behavior at contact point due to application of the dynamic load is considered.

***Key Words*- Blast Load, Soil Models, Foundation- Structure Interaction,Abaqus Modelling**

INTRODUCTION

In the past few decades considerable emphasis has been given to problems of blast and earthquake. An explosion is defined as a large-scale, rapid and sudden release of energy. Explosions can be categorized on the basis of their nature as physical, nuclear or chemical events. Explosive materials can be classified according to their physical state as solids, liquids or gases. Solid explosives are mainly high explosives for which blast effects are best known. Examples include trinitrotoluene (TNT) and ANFO (1).

Structures designed to resist blast loads are subjected to completely different type of load than that considered in conventional design. Here they are hit with a rapidly moving shock wave which may exert pressures many times greater than those experienced under the greatest of hurricanes**(1).** However, in blast phenomenon, the peak intensity lasts for a very small duration only. To design a structure capable of resisting these intense but short duration loads, members and joints of building frame and contact of foundation-soil are permitted to deflect.

DYNAMIC LOADS

- Earthquakes.
- The effects from bomb blasts.
- Operation of very heavy or unbalanced machinery, mining, construction (such as pile driving, deep dynamic compaction, etc), heavy traffic, wind and wave actions.

So, dynamic loads may be of various types. For example, some of the examples are given earthquake load is a dynamic load because this load varies with respect to time.Then of course, blast load is another type of dynamic load because here also the load varies with respect to time. Impact load is another example of dynamic load.**(7)**

The finite element method is nowadays the most frequently used computational method in engineering problems. In this numerical technique all complexities of a problem such as shape, boundary and loading conditions are kept the same but the results obtained are approximate. When using this method, calculations are robust due to the large number of unknowns leading to a large pile of simultaneous equations for the user to solve. Hence the use of computer programs to take care of these equations is one face of the method.If the location of the ground zero and the size of bomb are known,the corresponding blast loading for an existing structure may be found and the corresponding stresses and displacement at the contact point of the soil and foundation and foundation and frame can be known.

LITERATURE REVIEW

The analysis of the blast loading on the structure started in 1960's. US Department of the Army, released a technical manual titled "structures to resist the effects of accidental explosions" in 1959. The revised edition of the manual TM 5-1300 (1990) most widely used by military and civilian organization for designing structures to prevent the propagation of explosion and to provide protection for personnel and valuable equipments.

The methods available for prediction of blast effects on buildings structures are:

- Empirical (or analytical) methods
- Semi-empirical methods
- Numerical methods.

T.Ngo et.al. (1) studied blast loading and blast effects on structures, loss of life and injuries to occupants can result from many causes, including direct blast-effects, structural collapse, debris impact, fire, and smoke. The indirect effects can combine to inhibit or prevent timely evacuation, thereby contributing to additional casualties. In addition, major catastrophes resulting from gas-chemical explosions result in large dynamic loads, greater than the original design loads, of many structures.

Amir Younespour et.al.(2) studied on numerical evaluation of the effect of soil type on the behavior of underground structures against explosion and founded that analysis of the behavior of structures against explosion is very essential. In numerical simulation different amounts of explosive charges and different locations have been considered.

BLAST PHENOMENON

Let it be assumed that it is required to determine the net horizontal pressure Pnet that acts on the rectangular structure above ground building frame with soil connection in Fig 4.1. The structure is assumed to be subjected to a peak overpressure, which is produced by a TNT of 0.1 tonne at different distances(20m,30m) from the ground zero.

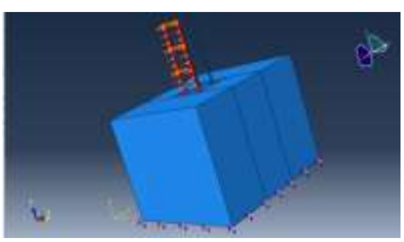

Fig.-1 Frame with applied blast load

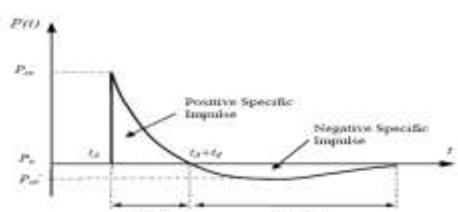

Fig.-2 The variation of overpressure with distance at a given time from centre of explosion.

The calculated value time and pressure for blast of 0.1TNT from IS:4991-1968 for distance of 20m and 30m has shown in the

Table-1

Distance (m)	P_{SO} (kg/cm^2)	p_{ro} (kg/cm^2)	q_o (kg/cm^2)	t_o (millisecond)	t_d (millisecond)	C_d	P_{net} (kg/cm^2)
20	0.72	1.856	0.17	14.06	9.612	-0.4	0.692
30	0.35	0.81	0.042	17.5	15.1	-0.4	0.33

PLASTICITY MODELS FOR SOIL-FOUNDATION INTERACTION

The elastic property of the soil represented using a spring, the plastic property of the soil is represented using a slider and the viscous property of the soil is represented using a dashpot. **(**P.E.Kavitha et al, **2011) (14).**

ELASTIC MODELS

In this type of model, soil behavior which exhibit purely elastic characteristic is considered. The simplest type of idealized soil response is to assume the behavior of supporting soil medium as a linear elastic continuum. Here the deformations are assumed as linear and reversible.

WINKLER MODEL

The idea of the Winkler foundation model is to idealize the soil as a series of springs which displace due to the load acting upon it. A demerit of the model is that it does not take into account the interaction between the springs. The soil is also described according to the linear stress-strain behavior.

ELASTIC CONTINUUM MODEL

In elastic continuum model the continuous behavior of soil is idealized as three dimensional continuous elastic solid. In this case the soil surface deflections due to loading will occur under and around the loaded region. The distribution of displacements and stresses in such media remain continuous under the action of external force system.

MOHR-COULOMB MODEL

It is an elastic-perfectly plastic model **.**The set of parameters adopted to represent the model are: young's modulus, poisson's ratio, friction angle, cohesion and the dilatancy angle. For each sublayer a linear variation of the young's modulus has been assumed. As the model does not allow to change the soil stiffness within the strain level, a reduced static stiffness has been adopted during the preliminary costruction stage.

FINITE ELEMENT MODEL

A finite element model for simulation of the soil behavior under blast loading has been made. The model consist of the following elements: SOIL BASE ,SOIL-TET, FOUNDATION ,FRAME OF BEAM & COLUMN

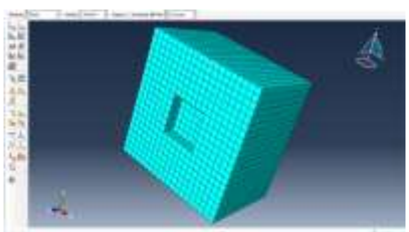

Fig- 3 Soil Base With Meshing

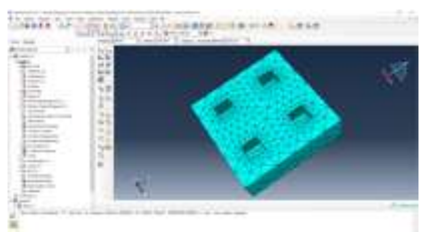

Fig- 4 Soil-Tet With Meshing

A soil base model of dense sand (Modulus of elasticity = 19620 N/M^2) has been prepared on Abaqus a simulating software.

- **Size of soil base:** 40*40*30 m^3
- **Groove size:** A groove of size 12*12 m^2 has been made on the soil base with 4m depth.
- **Poisson Ratio :**0.25
- **Mesh size of the soil base**: 0.5m

A soil tet model of dense sand (Modulus of elasticity =2.8*10^6 N/M^2) has been prepared on Abaqus a simulating software:

- **Size of soil tet:** 12*12*4 m^3
- **Groove size:** A groove of size 2*2m^2 has been made on the soil tet with 2m depth.
- **Poisson Ratio :**0.25
- **Mesh size of the soil tet**: 0.5m at contact of soil base side and in the groove of the foundation. At top face of the soil tet the mesh size is 1m.

Fig- 5 Foundation with mesh

Fig.-6 Frame of beam and column

The foundation of concrete to fit in the groove of the soil tet has been prepared (Modulus of elasticity =27.39*10^9 N/M^2) on Abaqus a simulating software:

- **Size of foundation:** 2*2*2 m^3
- **Poisson Ratio :**0.3
- **Mesh size of the foundation**: 0.5m

The frame made with beam and column has to be fitted at the base and centre of the foundation has been modeled on Abaqus.

- **Size of beam & column :** 6* 6 m^2
- **Cross section of beam and column:** 0.3*0.3m^2
- **Poisson Ratio :**0.3
- **Mesh size of the frame**: 1.2m

RESULTS AND DISCUSSIONS

There are four nodes which has been selected for study of the different type of stresses due to application of Blast pressure on at the distance of 20m and 30m.

Following are the stresses which has been calculated for analysis:

1. Maximum principal stress (abs)
2. Misses stress
3. Deflection

NODE-1: Interaction point of **soil-tet and foundation** on the face of applied blast pressure.
NODE-2: Interaction point of **column and foundation** on the face of applied blast pressure.
NODE-3: Interaction point of **soil tet and foundation** in the opposite side of the face of applied blast pressure.
NODE-4: Interaction point of **column and foundation** in the opposite side of the face of applied blast pressure.

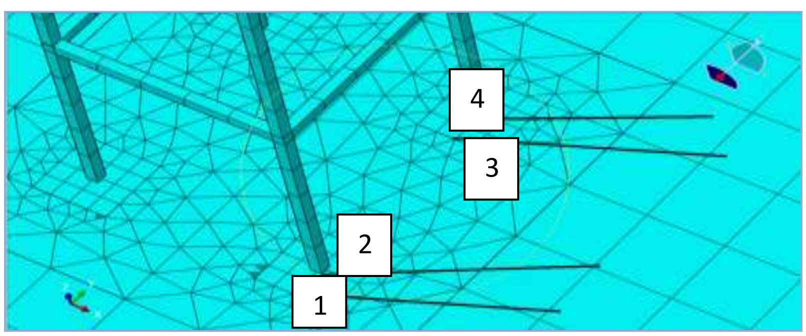

Fig- 7 Nodes selected for analysis

(A) Misses Stresses At Nodes 1,2,3,4 For 30m & 20 M Distance

Distance	Time (Millisecond)	Node-1(n/m^2)	Node-2(n/m^2)	Node-3(n/m^2)	Node-4(n/m^2)
30m	15	2.49378	624.21*10^6	1.565*10^{-13}	149.698*10^3
20m	9	8.16165	240.28*10^7	1.99*10^{-13}	930.557*10^3

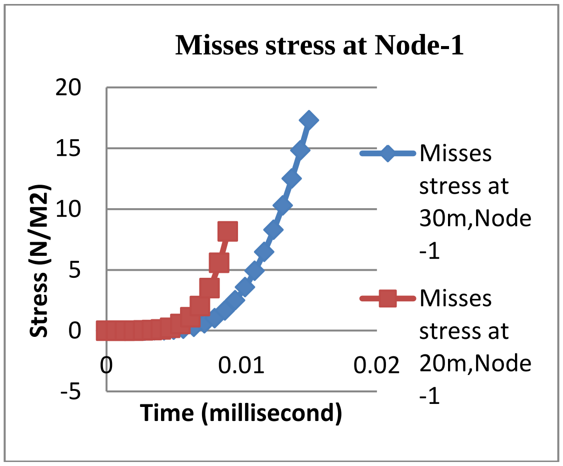

Fig.-8 Variation of Misses stress with time at Node 1

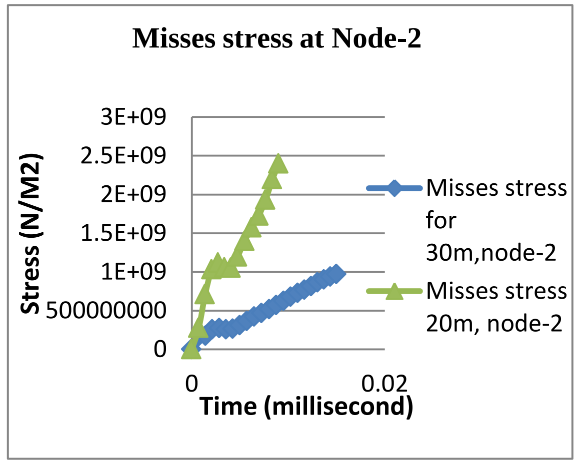

Fig.-9 Variation of Misses stress with time at Node 2

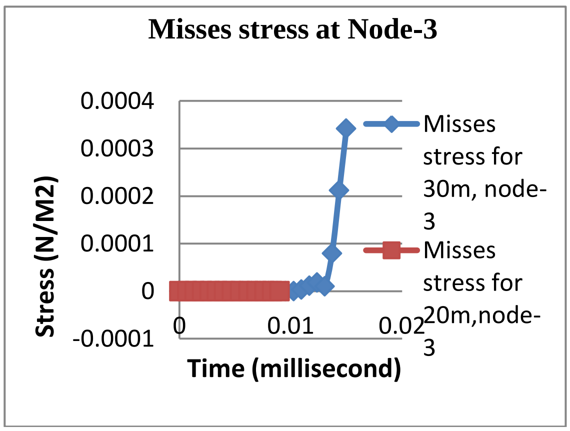

Fig.-10 Variation of Misses stress with time at Node 3

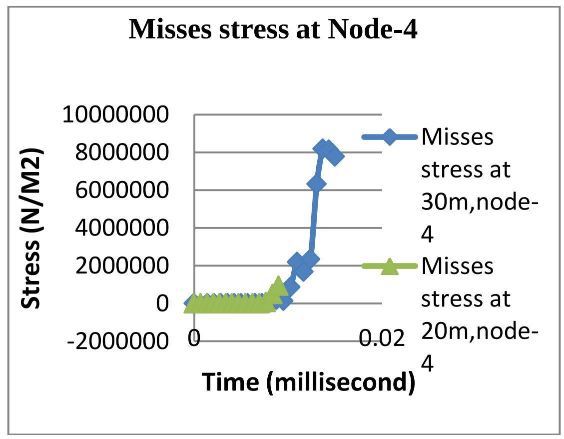

Fig.-11 Variation of Misses stress with time at Node

(B)Maximum Principal Absolute Stress At Nodes 1,2,3,4for 30m & 20 M Distance

Distance	Time (Millisecond)	Node-1(n/m^2)	Node-2(n/m^2)	Node-3(n/m^2)	Node-4(n/m^2)
30m	15	-3.17318	$390.635*10^6$	$-2.1523*10^{-13}$	$-296.510*10^3$
20m	9	-9.19466	$224.793*10^7$	$-2.414*10^{-13}$	$-217.055*10^3$

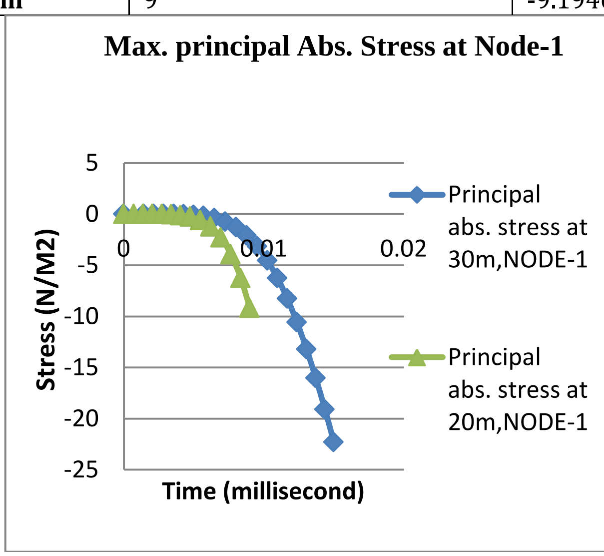

Fig-12 Variation Of Max. Principal Abs. Stress With Time At Node 1

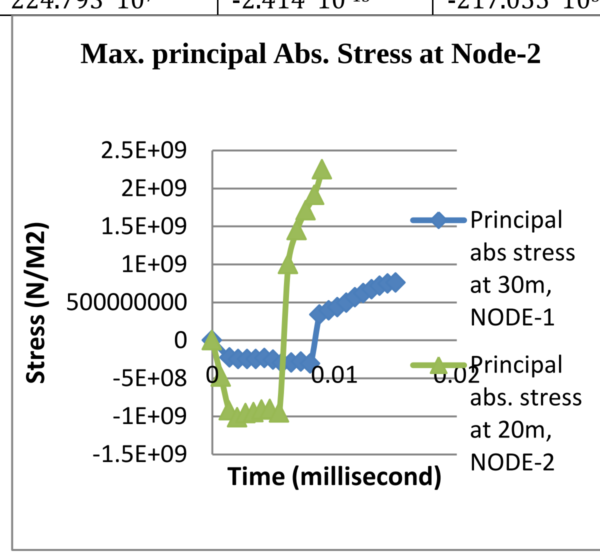

Fig-13 Variation Of Max. Principal Abs. Stress With Time At Node-2

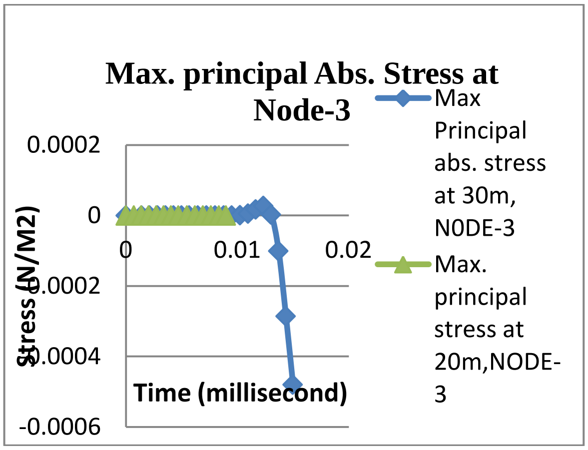

Fig-13 Variation Of Max. Principal Abs. Stress With Time At Node 3

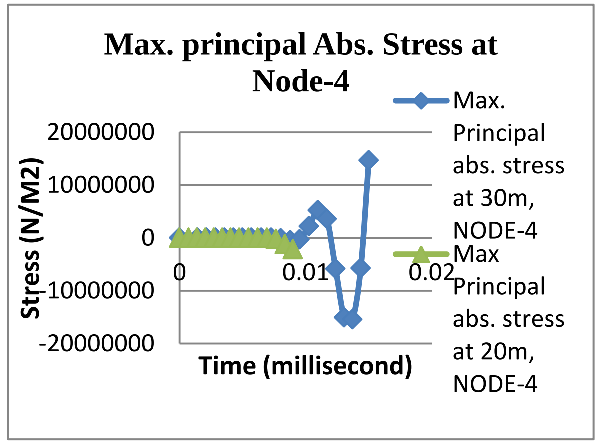

Fig-14 Variation Of Max. Principal Abs. Stress With Time At Node-4

(C) Displacement At Nodes 1,2,3,4 For 30m & 20m Distance

Distance	Time (Millisecond)	Node-1(m)	Node-2(m)	Node-3(m)	Node-4(m)
30m	15	$1.681*10^{-8}$	1.4425	0	$4.03*10^{-5}$
20m	9	$4.4721*10^{-8}$	4.8	0	$7.974*10^{-5}$

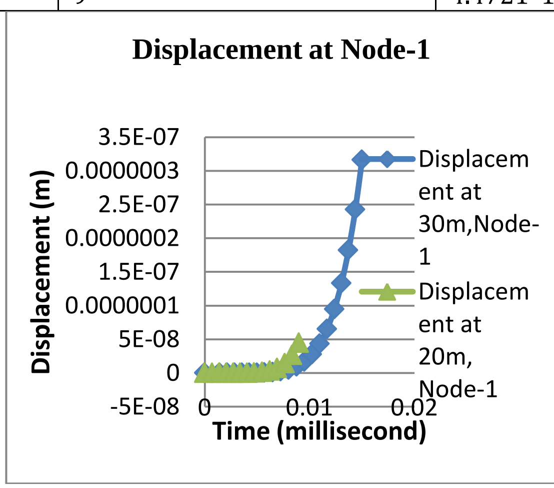

Fig- 15 Variation of Displacement with time at Node 1

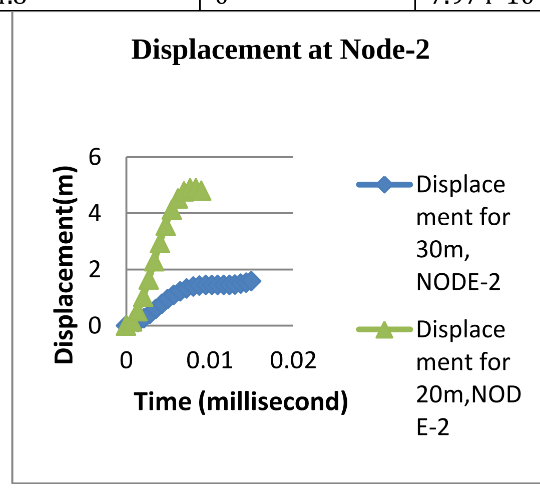

Fig- 16 Variation of Displacement with time at Node 2

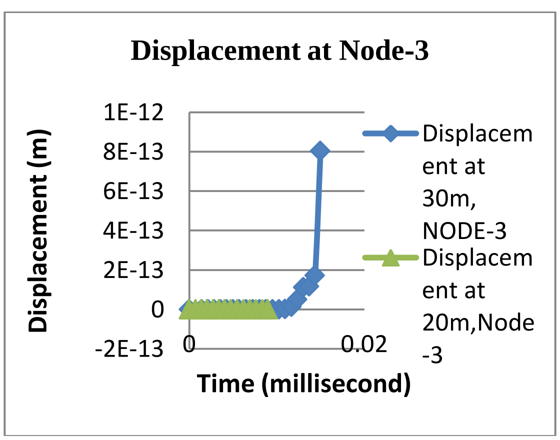

Fig- 16 Variation of Displacement with time at Node 3

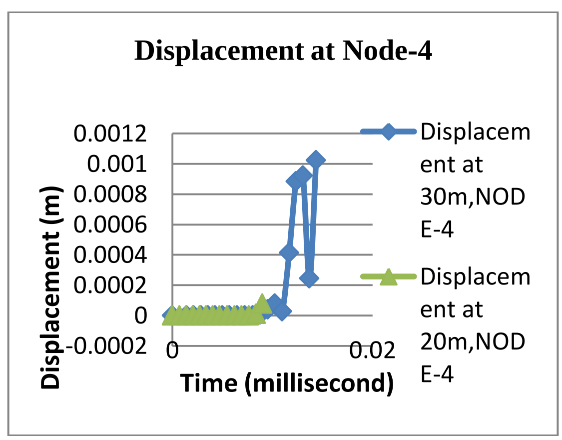

Fig- 17 Variation of Displacement with time at Node 4

CONCLUSIONS

- For the behavior of shallow foundation on Multi-Story building Frame subjected to blast loading a 3story one bay bare frame has been taken and blast load at a distance of 20m & 30 m of 0.1tnt has been applied on ABAQUS,conclusions as follows:

i. The objective of the analysis is to understand the response of the interaction point of soil-tet and foundation and column and foundation in shallow foundation choosen.

ii. Results of the analysis shows that exterior columns exposed are the most inflicted with damage due to the blast loading.

iii. It also shows that Misses stresses, Maximum principal absolute stress and displacement at the interaction point of soil-tet and foundation at Node-1to Node-4 for 30m distance at 0.009 second is less as compared to same pressure load on at 20m distance.

iv. Plot of various stresses and displacement with respect to the time show the variation. Excessive damage also occurs to beams of the first span behind the external column.

v. Various joints of the frame experienced stress concentration and damage in concrete and soil.

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