

decreasing trend. This implies for a decrease in the annual rainfall for the study area. Such deviation in climate is never desirable. This may lead to drought like conditions in future.

5. CONCLUSION

Quantification of climate change is very necessary to cope up with ever changing conditions. The trend analysis is made for Raipur district of Chhattisgarh for monthly rainfall data for the period of 1901-2002 is performed using non-parametric Mann-Kendall and Sen Slope Estimator test. The results reveal a downward trend for most of the months of a year for the period under investigation. Since the months of Southwest monsoon i.e. June-September shows a significant decreasing trend, it can be inferred for the annual rainfall over Raipur to be decreasing.

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Seismic Responses from Heterogeneous Geological Media with Horizontal and Vertical Fractures

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ABSTRACT

In this article the problem of wave propagation in fractured geological medium was investigated. The near borehole area with the water-soil contact was taken into account. For computer simulation the numerical grid-characteristic method on rectangular grids was used. In 2D approximation screenshots for wave fields at a sequence of times were computed. The analysis of cracks orientation\saturation influence on seismic response was carried out.

1. INTRODUCTION

Usually geological media are substantially heterogeneous. Ten large earthquakes have occurred in the last two years costing a huge loss of life and property. Thus, the study of seismic activity in geological media is the important research problem. The approach that is used was developed at Moscow Institute of Physics and Technology (Moscow, Russia) and it is based on the solution of full elastic medium equations with grid-characteristic numerical method. The results of modelling are viewed using ParaView software. The grid-characteristic method for forward modelling of dynamic processes in geological medium was initially proposed by Kholodov and Petrov (Magomedov et al., 1969; Petrov and Kholodov, 1984; Golubev et al., 2013). Later it was improved to provide monotonic solutions, eliminate non-physical oscillations and obtain fifth-order precision.

This new technique was successfully used in 2D for modelling of seismic responses from fractured geological media (Leviant et al., 2014). The described method is able to take the mentioned peculiarities of heterogeneous geological media into consideration. It allows us to construct the correct algorithms on the contact boundaries and on the boundaries of the integration domain; to take into consideration the internal property of mathematical system (propagation of discontinuities along characteristic surfaces).

In this article the splitting of the whole domain into a set of rectangular grids whose vertices are defined as nodes was used. Appropriate contact conditions were set between them for propagation of waves. The subsurface explosion leads to the creation of full spectrum of volumetric wave: pressure waves (P-wave) and shear waves (S-wave).

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2. PROBLEM STATEMENT

The investigated physical problem consists of a borehole of 20 meter diameter and 200 meter depth surrounded by soil of 1 km length. Below the borehole there is an elastic medium of 1 kilometre depth. The model consists of more than 24 lakh nodes.

The explosion in borehole is of magnitude 1 cm/sec in vertical direction only. The medium inside borehole is assumed to be water (in elastic approximation). The velocity of P wave and S wave in soil and elastic medium is taken 4190 m/sec and 2093 m/sec respectively while in air the velocity is taken as 1330 m/sec for P wave and 19 m/sec for S wave. In general, the grid-characteristic approach provides the facility to model pure acoustic case, but it is necessary additionally to combine acoustic solution in water and elastic solution in soil. Two different geometrical cases were analysed – with horizontal and vertical cracks. We also modelled fluid-filled and gas-filled cracks.

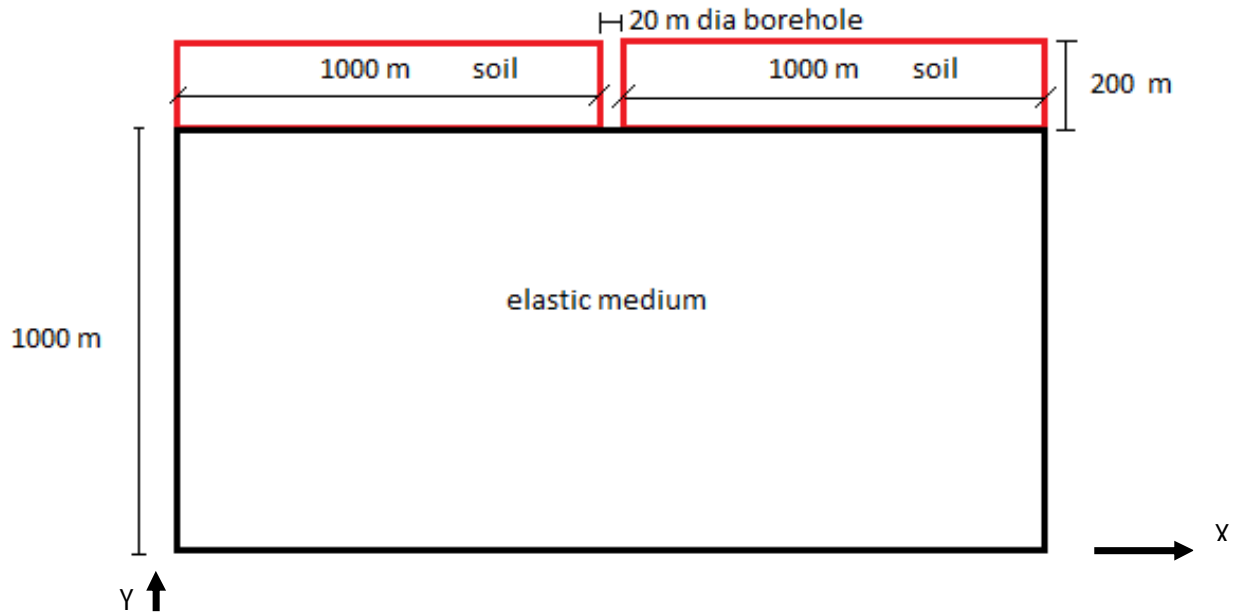


Figure 1: General layout of model used

Table 1: Different cases of models used

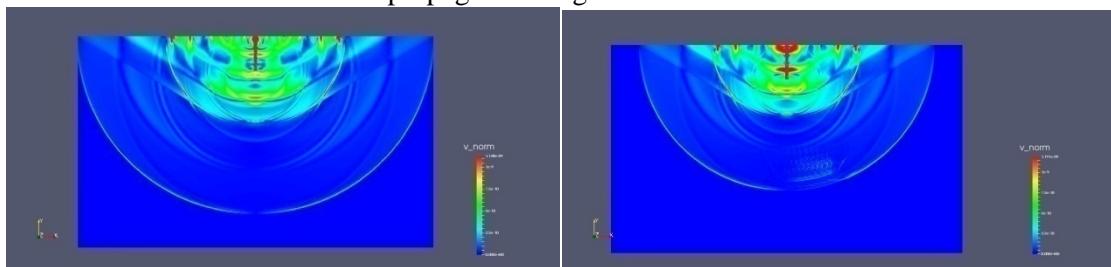
S.no.	LOCATION OF CRACKS	DISTANCE BETWEEN CRACK (METERS)	LENGTH OF CRACK (METERS)	TYPE OF CRACK
1	1000-1300 meters in X direction 500 meter in Y direction	30	100	Vertical gas filled
2	1000-1300 meters in X direction 500 meter in Y direction	30	100	Vertical fluid filled
3	500-1100 meters in X direction 500 meter in Y direction	30	100	Vertical gas filled
4	500-1100 meters in X direction 500 meter in Y direction	30	100	Vertical fluid filled
5	500-1000 meters in Y direction 1000-1300 meter in X direction	30	300	Horizontal gas filled
6	500-1000 meters in Y direction 1000-1300 meter in X direction	30	300	Horizontal fluid filled
7	500-1000 meters in Y direction 700-1300 meters in X direction	30	600	Horizontal gas filled
8	500-1000 meters in Y direction	30	600	Horizontal fluid filled

	700-1300 meters in X direction			
9	500-1100 meter in X direction 500 meter in Y direction	15	100	Vertical gas filled
10	500-1100 meter in X direction 500 meter in Y direction	15	100	Vertical fluid filled

3. RESULTS AND COMPARISION OF MODELS

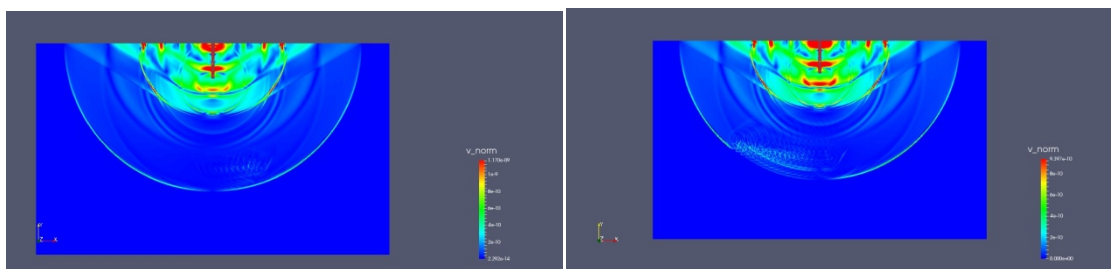
The results obtained are viewed using ParaView software and are compared between different models. Screenshots for comparison between different models of vertical fractures are taken at step 2000 and at step 1500 for horizontal fractures.

From the images it can be observed that in case of homogeneous medium i.e. with no obstacles the waves propagate smoothly without showing any deviations. In the case of vertical cracks that are gas-filled the most part of the wave can be seen being interacted with the cracks and getting deviated from its original path. In the case of vertical cracks that are fluid-filled it can be seen that the P-waves change their intensity but propagate through them and are not getting distorted and since the material is fluid therefore shear waves do not propagate through it.



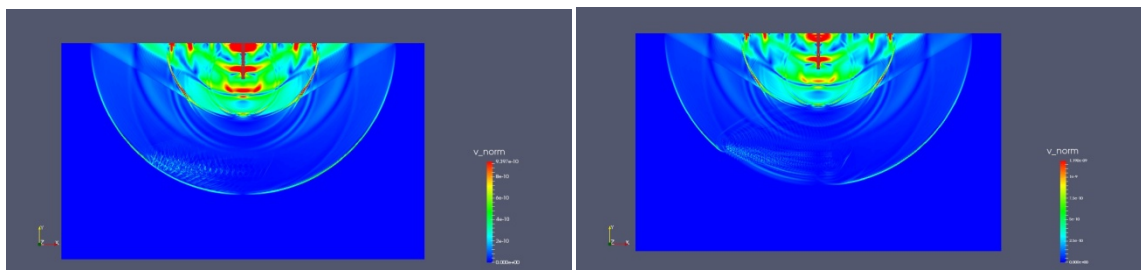
(a) without cracks

(b) 300m crack, gas-filled



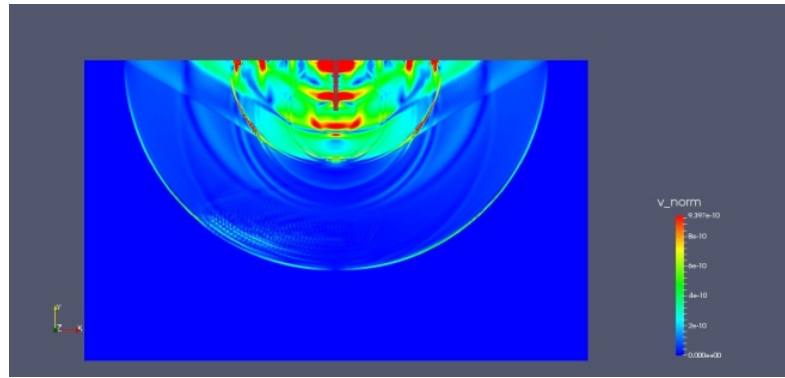
(c) 300m crack, fluid-filled

(d) 600m crack, gas-filled



(e) 600m crack, fluid-filled

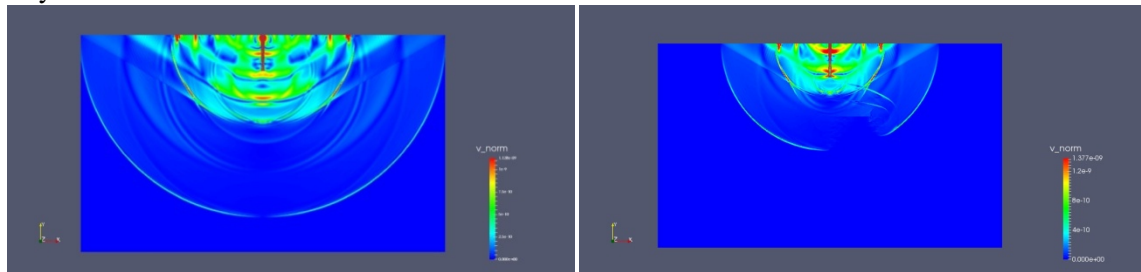
(f) 600m crack, gas-filled with increased density



(g) 600m crack, fluid-filled with increased density

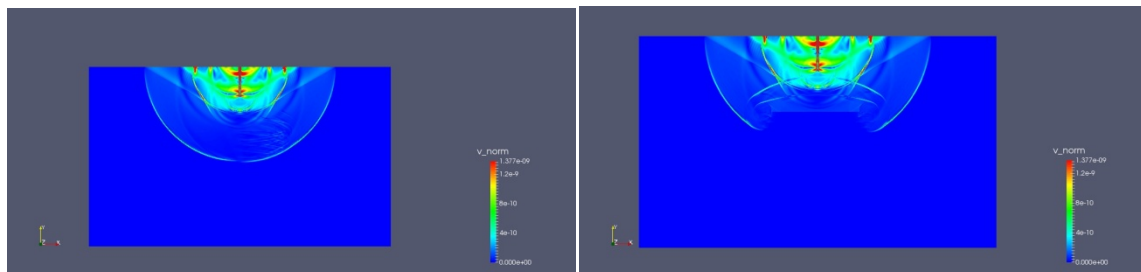
Figure 2: Screenshots of models with vertical cracks

Similarly, in the case of horizontal cracks the waves are reflected back when they come in contact with crack that are gas filled and most part of the waves change intensity and are reflected less when they interact with cracks that are filled with fluid.



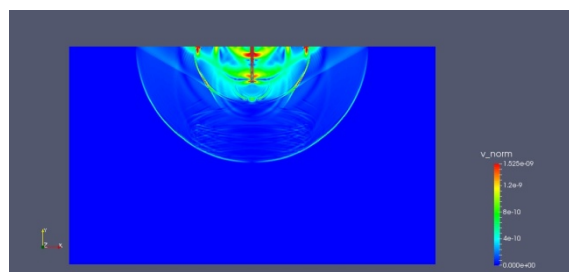
(a) without cracks

(b) 300m crack, gas-filled



(c) 300m crack, fluid-filled

(d) 600m crack, gas-filled



(e) 600m crack, fluid-filled

Figure 3: Screenshots of models with horizontal fractures

4. CONCLUSION

- The waves become weaker while interacting with geological fractures;
- The responses even from vertical cracks are anisotropic (not equivalent for X and Y axis);
- Reflections from dry fractures are stronger than for fluid-filled fractures.

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