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Study of Seismic Wave Phenomenon

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ABSTRACT

This paper throws light on the concept of wave propagation. This article mainly focuses to introduce the subject seismology, seismic waves and its types, earthquakes etc. and basic preliminaries related to the subject. Since, the wave propagation is an essential and important phenomenon in various fields like geophysics, seismology, mechanics, fluid dynamics etc., so it may be very helpful for the early researchers to do their research in these fields. The present theoretical results may provide useful information for experimental scientists, researchers and seismologists those who are working in the area of wave propagation in different type of porous media.

Keyword: Wave Propagation, Seismology, Earthquake, Seismic Waves.

I. INTRODUCTION

Wave is a form of energy which is transmitted from one place to another, in a medium, sometimes with small or no permanent displacements of the particles of the medium. Wave propagation is the way in which wave propagates in any medium. Therefore, in wave propagation, the particles oscillate about its mean position without change in its original positons. On the basis of direction of the oscillation with respect to the propagation direction, we can classify between different types of waves. The theory of wave propagation in solids was mainly developed in the 19thto 21stcenturies by Possion [1], Kelvin [2], Rayleigh [3,4,5], Stoneley [6],Love [7], Biot [8], Stokes [9], Poonia and Kharb [10], Poonia and Sonu [11]and many others. With the help of seismology we are able to get better understanding of the concept of waves. Mainly, the word Seismology is combination of two Greek words 'Seismos' meaning earthquake and 'Logos' meaning study. Seismology is defined as the study of vibrations of the Earth's interior caused by natural and unnatural sources, such as earthquakes. A person who is skilled at, professes, or practices seismology is called as a seismologist. Seismograph is an instrument used

to measure the movement of earthquakes. A weight is suspended in a manner that permits it to stay still when the ground moves. Most present day instruments utilize an electromagnetic component for this. The modern earthquake monitoring instruments use seismometer and record the movement of earthquake digitally. Seismometer is the instrument that measures the motion of the ground on which it is positioned, in the form of seismograms. Now a days, seismology plays a vital role in the geophysics and Earth sciences and it is difficult to understand seismology without seismographs. Seismology is categorized into three parts which are observational seismology, engineering seismology, and physical seismology. The seismology which record the earthquakes (micro seismology) and observe the effects of earthquake (macro seismology) is known as observational seismology. Engineering seismology deals with the determination of seismic hazards and risks. Physical seismology is the study of the properties of the Earth's interior and physical characteristic of seismic sources. In next part of the paper we will discuss the meaning and source of earthquakes, seismic waves and its classifications, some other types of waves, and finally the observation of the study presented in detail. Mainly, some basic termology of wave propagation is discussed in detail in this paper and will be very helpful for the students having seismology background who wants to do their research in the field of wave propagation.

2 Earthquakes

The Earth had suffered hundreds of millions of earthquakes in its formatives stage, before the human race came into existence. In the old days people used to think of earthquakes as a curse of the Gods like other natural disasters. It is only in the seventeenth century or the mid of seventeenth century that the earthquake was viewed as geological process. Since then systematic data and observations were recorded and utilizing these observation, people tried to understand the earthquake phenomena occurring in the Earth's geological process. This data also helps in providing the methods for the rational design and analysis of structure against earthquake. Earthquake is sudden and transient disturbance or motion on the surface of Earth produced due to geological disturbance within the Earth itself. The Earth's tectonic plates are made of elastic and brittle rocky material, which also keeps sliding, very slowly against each other. And when the plates are not able to store the energy anymore, they snap. This sudden slip at the fault releases the stored elastic energy and causes earthquakes and the intensity of earthquakes is recorded with the help of seismograph. The released energy is enormous and travel in all directions, the point where the energy is released, is called the focus of an earthquake or another term given to it is hypocentre. Above the focus there exist a geographic area on the surface of the Earth called as epicentre. These seismic waves can be noticed by the penetrating devices thousands of miles from the centre. The effects of the earthquake are shaking of the top layer of the Earth and ground rupture, soil liquefaction, landslides, fires, tsunami and floods etc. Figure 1 represents the image of earthquake and has been taken from the source [12].

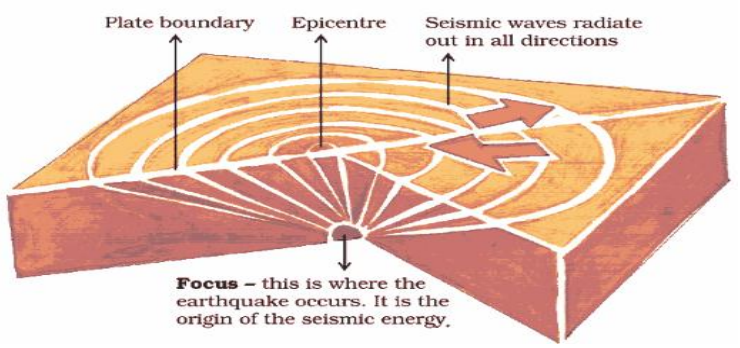

Figure 1: Image of Earthquake

III. SEISMIC WAVES

Seismic waves are the vibrations which travel in the Earth's layer and are the result of earthquakes, volcanic ejections, magma movement and the man made blasts. There is huge amount of energy stored inside the Earth and that energy in released in the form of elastic waves, called seismic waves. This released energy causes huge damage such as destruction of buildings, individual properties etc. Seismic waves are broken into two categories body waves and surface waves. Body waves include P-waves and S-waves and surface waves are also well-known as Love, Rayleigh and Stoneley waves. The detail of these are as under:

3.1 Body Waves

Body waves may be defined as the wave which moves in the interior of the Earth or within a body of rocks. Body waves generally have lesser amplitudes and shorter wave distances as compared to surface waves and these waves travel with higher speeds. They have lesser particle motion due to which body waves causes less destruction compared to surface waves (another type of seismic wave). Body waves may be classified into two categories on the basis of particle motion: primary body waves and secondary body waves.

3.1.1 Primary Waves

Primary waves the first type of body waves and these waves also known as P-waves. P-waves are compressional and push-pull waves which means that the motion of molecules in a solid, as the seismic waves pass through, is in the same direction as the waves propagates through the materials. These waves are called primary because these waves are the first to reach on seismographic station as the velocity of these waves are higher than the other forms of waves. The main characteristics of P-waves are that they travel with speed of sound. Primary waves can travel through any type of materials like solid, liquids and gases. Materials do not matter in case of primary waves. Through the materials, the speed of these waves is about 5 kilometres per second. Certain creatures such as dogs, can feel the P-waves much before an earthquake. Humans can only feel the ramifications it has on the crust. Examples of P-waves are sound waves and waves in a stretched spring. Figure 2 illustrate the image of primary waves and have been taken from the source [12].

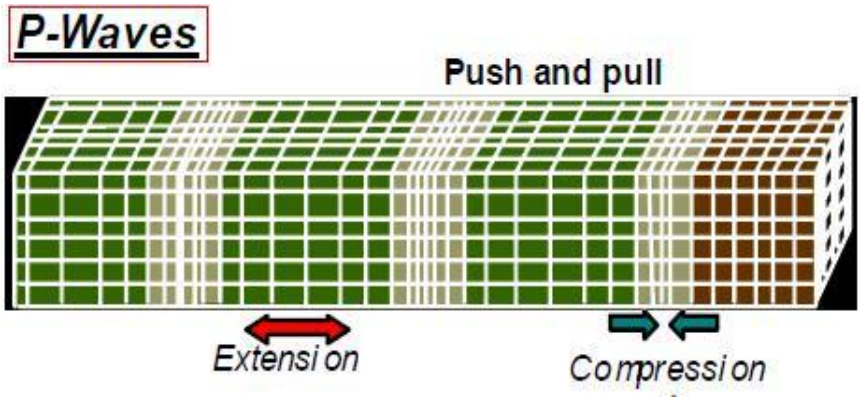

Figure 2: Image of P-Waves

3.1.2 Secondary Waves

Secondary waves are the second kind of the body waves and are also known as S-waves or shear waves. Actually, the motion of particles is perpendicular to the direction of propagation through the material. S-waves are always the second one to reach at seismographic substations after the P-waves, hence, they are termed as secondary. They have the characteristics of transverse waves. These waves can be polarized into vertical and horizontal directions, which are known as shear horizontal waves (or SH-waves) and shear vertical waves (or SV-waves) respectively. Wavelength and speed of these waves are 3-4 kilometre per second. They are slower than P-waves and can travel through only the solid medium. By studying S-waves, scientists were able to predict that the outer core is purely liquid medium. Light waves and water waves are the example of S-waves. Fig 3 illustrates the image of secondary waves and has been taken from the source [13].

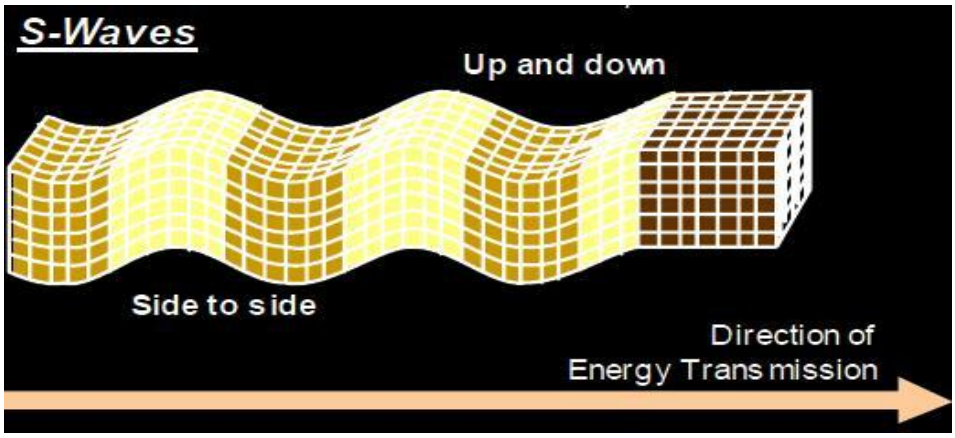

Figure3: Image of S-Waves

3.2 Surface Waves

Transmitted energy along Earth's surface and rocks move from side to side like snake and rolling pattern like ocean wave. These waves travel from the epicentre across the surface of the Earth. They are also responsible for the majority of the damage that is done during an earthquake. The deeper the earthquake happens, the less destructive the surface waves will be and that is because these waves can only occur on the surface of the Earth. If the earthquake occurs deeper in the Earth these waves have less energy by the time, they get to the surface. Surface waves travel slower as compared to body waves. The surface waves can be further broken down to the three waves which are well-known as Love, Rayleigh and Stoneley waves.

3.2.1 Love Waves

The first type of surface waves are known as Love waves or Q waves given by a British mathematician A.E.H. Love in 1911. Love wave are a combination of transverse and longitudinal waves. In Love waves particles moves backward and forward horizontally in zigzag. In other words, Love waves are kind of zigzagging left and right about the y-axis. They travel through both solids and liquids through all parts of the Earth. They travel and leads of course to the process of refraction as we go into denser materials. Love waves are slower than any type of body waves, but unlike S-waves, they cannot spread into water. They naturally travel slightly faster as compared to Rayleigh waves. Figure 4 illustrate the image of Love waves and have been taken from the source [14].

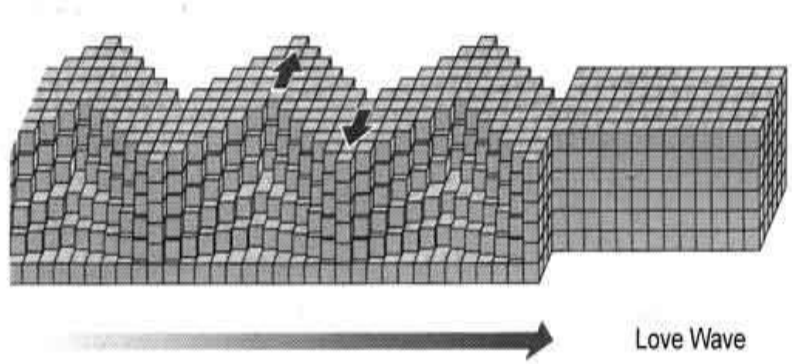

Figure 4: Image of Love Waves

3.2.2 Rayleigh Waves

Rayleigh waves are the second kind of the surface waves. These waves were first predicted by Lord Rayleigh in 1885. In Rayleigh waves the particles move elliptically like ripples in a pond and these are backwards in motion. The motion of Rayleigh wave is more unique, it is rolling. Most of destruction caused by earthquake is caused by Rayleigh waves and it is because these waves can be a lot bigger than other type of waves. Onlookers have to observe Rayleigh waves in enormous open spaces, such as car parkings, where they described the scene as vehicles moving up and down like corks floating on the ocean. Rayleigh waves are slower as compared to the body waves and typically travel with speed 10% slower than the S-waves. Rayleigh waves are used in geophysics and geotechnical engineering. Many mammals, insects and spiders can detect the Rayleigh waves of frequency less than 20 Hz. Many animals can

communicate through Rayleigh waves like elephant. Figure 5 illustrate the geometry of Rayleigh waves and have been taken from the source [15].

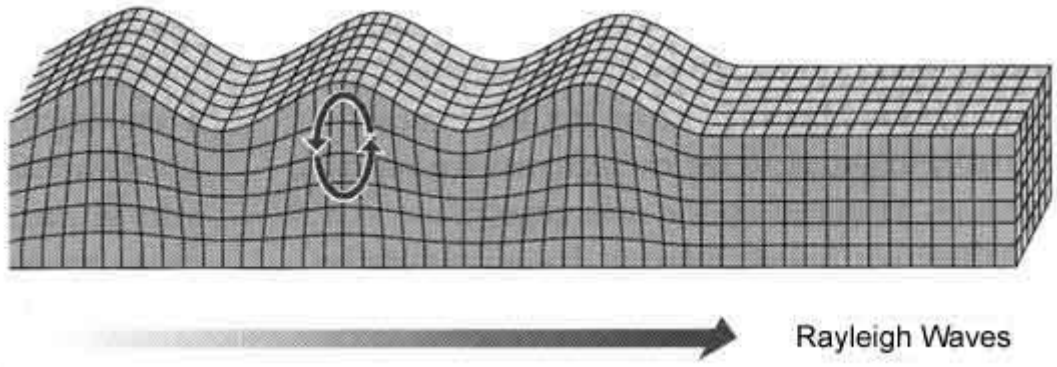

Figure 5: Image of Rayleigh Waves

3.2.3 Stoneley Waves

Stoneley waves also known as Scholte waves are the third kind of surface which mainly propagates along solid-solid interface. These waves were discovered by British seismologist Dr. Robert Stoneley in 1924. These waves have large amplitude interface or surface, wave was generated by a sonic tool in a borehole. These waves are used in the estimation of locations of fractures and permeability of the formation. Figure 6 illustrate the structure of Stoneley waves and have been taken from the source [16].

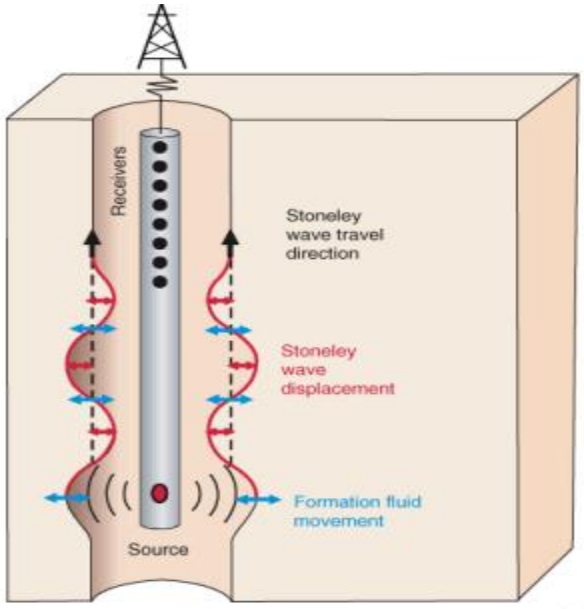

Figure 6: Image of Stoneley Waves

3.3 Some other types of Waves

There are many other kinds of waves such as longitudinal wave, transverse wave etc. and details of some of these are given below:

3.3.1 Longitudinal Waves

If the vibrations of the particle is in a direction that is the same as the direction of the propagation of waves or longitudinal waves are the waves in which the particles of the medium move back and forth in the direction of wave propagation, then the generated waves are termed as longitudinal waves. When disturbances travel, some part of the slinky are coming closer and other part of the slinky remains far apart. So, when distance travels, the parts of slinky that are coming closer to one another are known as compressions. And the parts of the slinky that are far apart from one another are known as rarefactions, or we can say that the compression moves ahead, it leaves behind parts of the slinky which is far away from one another. This is known as rarefaction. Figure 7 illustrate the image of longitudinal waves and have been taken from the source [17].

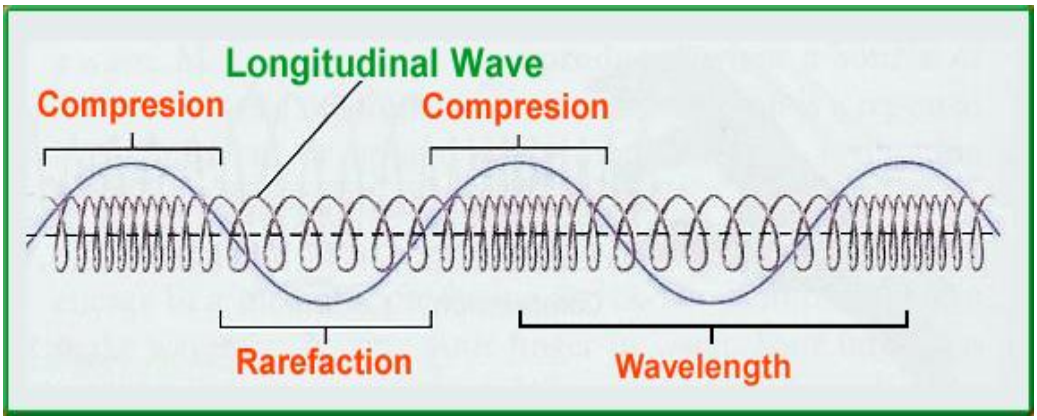

Figure 7: Image of Longitudinal Waves

3.3.2 Transverse Waves

In transverse waves, the vibration of the particles is in the direction normal to the motion of wave propagation. In other words, even though the disturbance is travelling in the forward direction; the particles are vibrating in their mean position in an up and down manner. Thus, we can clearly say that the direction is perpendicular, and the maximum displacement on either side of the mean position, is called amplitude. The maximum positive displacement of the particles from its mean position is known as the crust, and the maximum negative displacement or the minimum displacement of the particles from its mean position is known as trough. The distance between the crust and trough is called the wavelength. For example-waves that are formed on the surface of water when we throw a stone, or waves that are formed when we shake a rope up and down that is fixed at one end. All these various types of waves tell us about the structure of the Earth. Figure 8 shows the image of transverse waves and have been taken from the source [18].

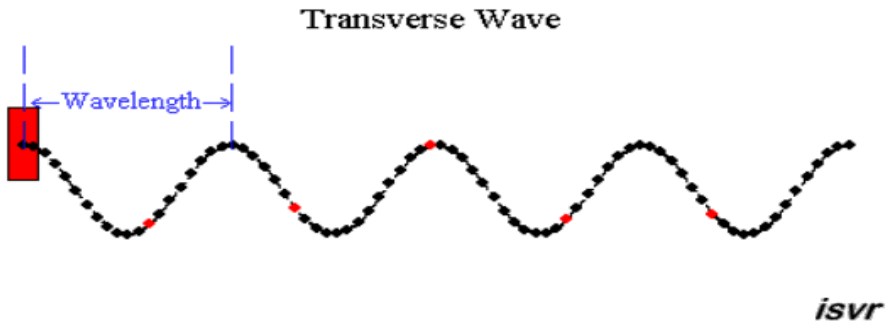

Figure 8: Image of Transverse Waves

IV. OBSERVATIONS

In this paper, we studied wave propagation, cause of earthquakes, seismic waves and their classification and some other type of waves in detail. So, this paper is very helpful to new researchers to do their research in the field of wave propagation as it provides a platform for them to understand the basic concepts of seismology.

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