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TREND ANALYSIS OF EARTHQUAKES IN INDIAN SUBCONTINENT IN LAST TWO DECADES

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Abstract: The Indian subcontinent has a history of overwhelming earthquakes. The main cause for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Asia at a rate of approximately 50 mm/year in north–east direction. Geographical statistics of India shows that almost 54% of the land is susceptible to earthquakes. In this paper, we analyzed the trend of earthquakes that occurred during 2000-2019 in Indian continent by the method of moving averages and fitting the curve to the past data. Here, the past behavior of seismic events of different magnitudes and fatalities due to this natural hazard during last two decades has been discussed.

Keywords: Trend Analysis, Earthquakes, Moving averages, Curve fitting.
2010 AMS Mathematics Subject Classification: 86A15, 86A17, 86A60, 86A99.

1. INTRODUCTION

Indian subcontinent has a very long history of witnessing numerous large earthquakes of high and very high intensities. Various geographical regions are categorized by the Geological Survey of Indian continent as regions of high seismic risk. Majority of these places are in the Himalayas [1], one of the most seismically active regions in the world. The major reason of occurrence of seismic events in these regions is due to the movement of the Indian plate towards the Asian plate at the rate of 50 mm per year[2].The Indian plate comprises most of South Asia i.e. the Indian subcontinent and a portion of the basin underneath the Indian Ocean, including parts of South China and western Indonesia. Geographical statistics of India show that almost 54% of the land is susceptible to earthquakes[3]. Besides the immediate obvious threats presented by an earthquake, it can also set off other several natural hazards and fatalities. Many researchers have studied the geological and tectonic behavior to understand the earthquake in the Himalaya and its adjoining regions [4,5,6,7].

In this paper, the trend of earthquakes has been studied that occurred during 2000-2019 in Indian continent by the method of moving averages and the method of curve fitting. Also the facilities due to natural hazard occurred has been studied.

2. TREND ANALYSIS BY THE METHOD OF MOVING AVERAGES AND FITTING OF TRENDLINES

Trend analysis enables us to study the past behavior of phenomenon under consideration, to determine the type and nature of variations in the past data.
Trend of any phenomenon can be studied and measured by Graphic Method, Method of Semi- Averages, Method of Curve Fitting by Principle of Least Squares and Method of Moving Averages.
To analyze the trend of earthquakes in the Indian subcontinent, the method of moving averages is adopted to measure the trend of earthquakes occurs in last two decades. Moving average of extent m is a series of successive averages of m terms at a time starting with Ist, IInd, IIIrd term etc. If m is odd =(2k+1) moving average is placed against the mid- value of the time interval it covers. If m is even =(2k), it is placed between the two middle values of the time interval it covers. Moving average method gives a correct picture of long term trend of the series. If the trend is linear or approximately linear and oscillatory movements affecting the data are regular in period and amplitude.

2 (a) According to magnitude (M_L), Earthquake can be classified into following six categories [7]

Table 1:

Sr. No.	Classification	Magnitude(M_L)
1	Great Earthquake	$8 \leq M_L$
2	Major Earthquake	$7 \leq M_L \leq 7.9$
3	Strong Earthquake	$6 \leq M_L \leq 6.9$
4	Moderate Earthquake	$5 \leq M_L \leq 5.9$
5	Light Earthquake	$4 \leq M_L \leq 4.9$
6	Minor Earthquake	$3 \leq M_L \leq 3.9$

2 (b) No. of earthquake according to above classification in last two decades

Table 2:

Sr. No.	Classification	No. of Earthquakes	Years of occurrence
1	Great Earthquake	1	2004
2	Major Earthquake	6	2001, 2005, 2009, 2015
3	Strong Earthquake	3	2002, 2011, 2016
4	Moderate Earthquake	6	2005, 2006, 2007, 2013, 2017
5	Light Earthquake	4	2005, 2006, 2008, 2019
6	Minor Earthquake	0	--

(Source: National Geophysical Data Center (NGDC))

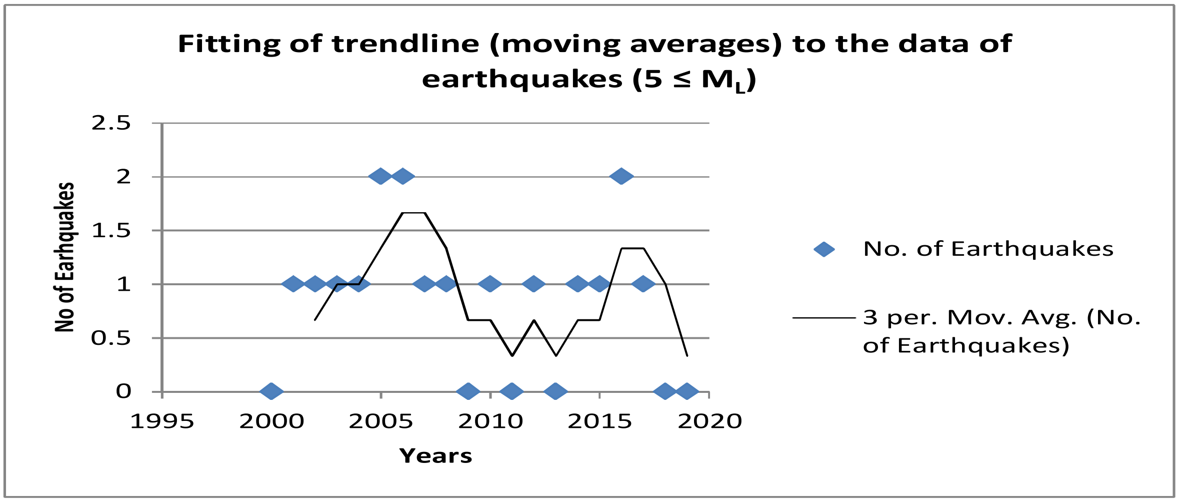
2 (c) Determination of the trend of earthquakes by the method of moving averages

Table 3:

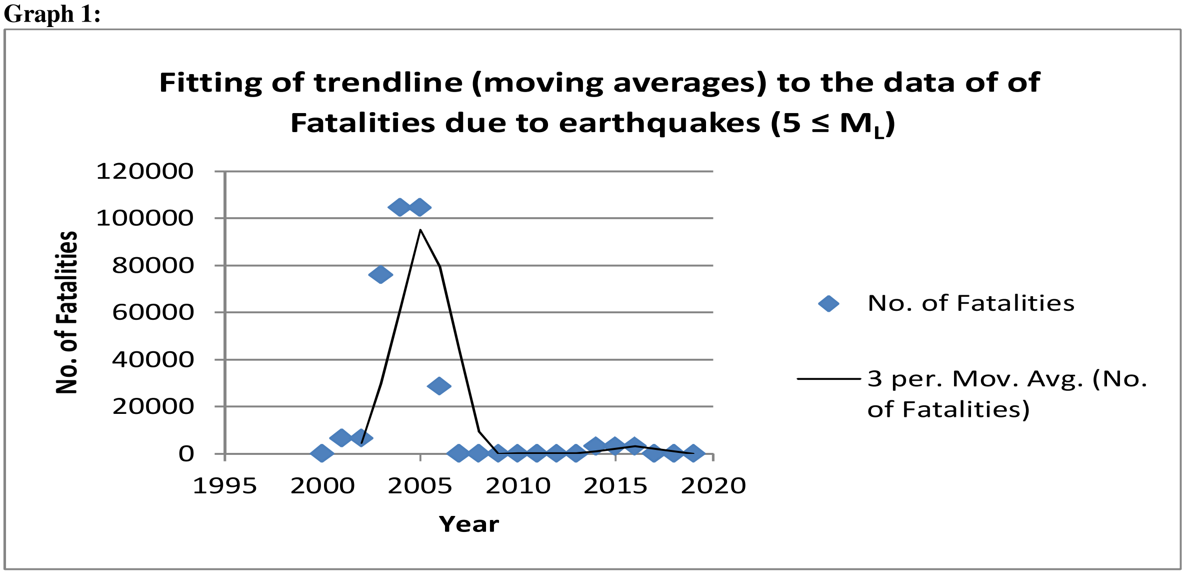
Years	Determination of the trend of earthquakes ($5 \le M_L$) and Fatalities due to earthquake by the method of moving averages				Determination of the trend of earthquakes ($5 > M_L$) and Fatalities due to earthquake by the method of moving averages			
	Number of Earthquakes (a_i , i= 1 to 20)	Trend value(3-year moving average) ($b_i = (a_{i-1}+a_i+a_{i+1})/3$), i= 2 to 19	Number of Fatalities (c_i , i= 1 to 20)	Trend value(3- year moving average) ($d_i = (c_{i-1}+c_i+c_{i+1})/3$), i= 2 to 19	Number of Earthquakes (a_i' , i= 1 to 20)	Trend value(3-year moving average) ($b_i' = (a_{i-1}'+a_i'+a_{i+1}')/3$), i= 2 to 19	Number of Fatalities (c_i', i= 1 to 20)	Trend value(3-year moving average) ($d_i' = (c_{i-1}'+c_i'+c_{i+1}')/3$), i= 2 to 19
2000	0	--	0	--	0	--	0	--
2001	1	1	20023	6675	0	0	0	0
2002	1	1	2	6675	0	0	0	0
2003	0	1	0	75967	0	0	0	0
2004	1	1	227898	104633	0	0	0	0
2005	2	2	86000	104633	1	1	1	1
2006	2	2	2	28668	1	1	1	1
2007	1	1	1	1	0	1	0	1
2008	0	1	0	0	1	0	1	0
2009	1	0	0	0	0	0	0	0
2010	0	1	0	37	0	0	0	0
2011	1	0	111	37	0	0	0	0
2012	0	1	0	38	0	0	0	0
2013	1	0	3	1	0	0	0	0
2014	0	1	0	3195	0	0	0	0
2015	3	1	9581	3197	0	0	0	0
2016	1	2	11	3198	0	0	0	0
2017	1	1	3	5	0	0	0	0
2018	0	0	0	1	0	0	0	0
2019	00	--	0	--	1	--	1	--

(Source: National Geophysical Data Center (NGDC))

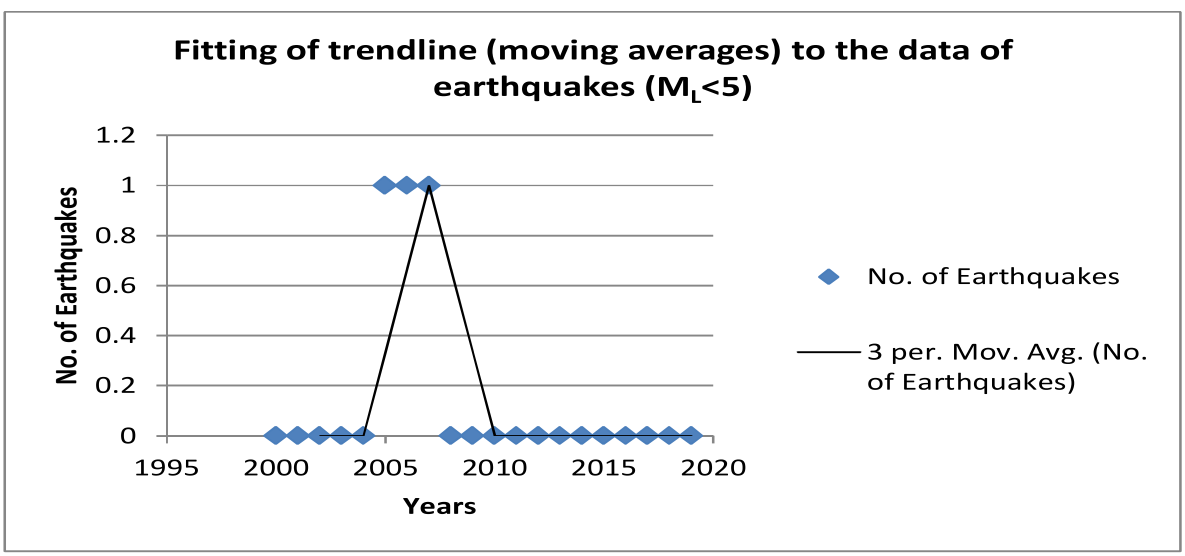
2 (d) Fitting of trendlines: **In this section trend lines have been fitted to the data (Table 3) of no. of earthquakes of magnitude greater than equal to 5 and less than 5 & no. of fatalities due to earthquakes of magnitude greater than equal to 5 and less than 5 & no. of earthquakes of different magnitudes.**



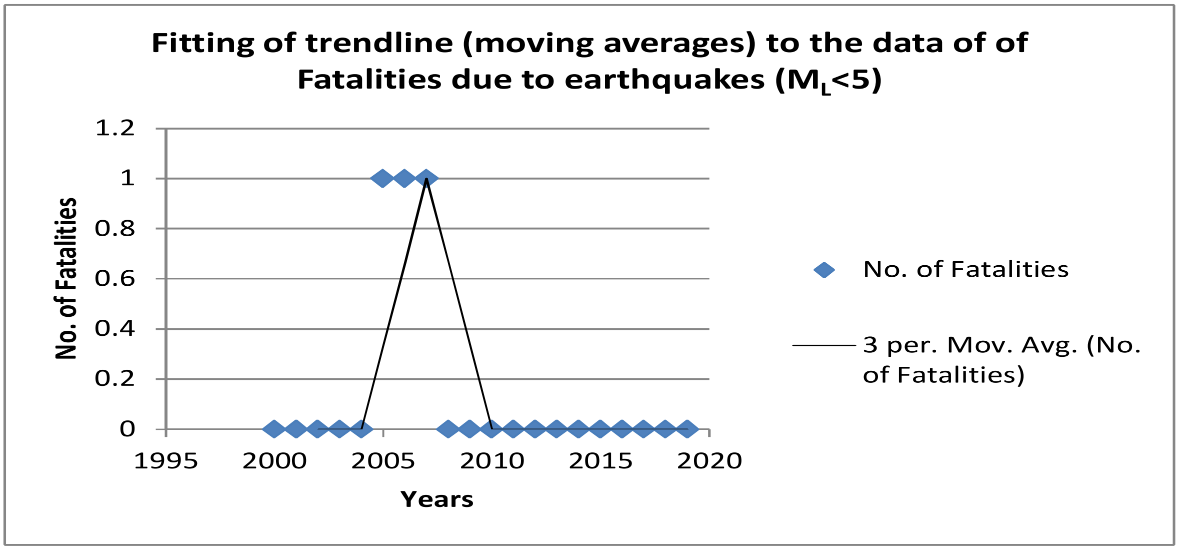
Graph 1:



Graph 2:



Graph 3:



Graph 4:

3. DISCUSSION

Earthquakes have been categorized according to the magnitude in Table-1. In Table-2, we have classified earthquakes according to their magnitude occurred in Indian subcontinent in the last two decades. We calculated the trend values(3-year moving average) of the data of number of earthquakes ($5 \leq M_L$) and fatalities due to earthquakes($5 \leq M_L$)&number of earthquakes ($5>M_L$) and fatalities due to earthquakes ($5>M_L$)in Table-3.In Graph-1 to Graph-4 trendlines (Moving Averages) have been fitted to the data given in Table-3.A cyclic fluctuation of earthquakes of magnitude ($5 \leq M_L$)has been observed in Graph-1. In Graph-2, it is observed that fatalities due to earthquakes of magnitudes ($5 \leq M_L$) have been reduced in last decades. It may be because of advancement in researches in the field of civil engineering, mechanical engineering, geotechnical engineering, structural engineering etc. It is observed that in Graph-3, the number of earthquakes of magnitude ($5>M_L$) were very less in comparison to the number of earthquakes of magnitude ($5 \leq M_L$) in last two decades. The Graph-4 i.e. the number of fatalities due to earthquakes of magnitude ($5>M_L$) is almost similar to the Graph-3 i..e.the number of earthquakes of magnitude ($5>M_L$).

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