Bull. Ind. Soc. Earthq. Tech. Paper No. 297, Vol.27, No.3, Sept. 1990, pp.121-132

DAMAGE SCENARIO OF A HYPOTHETICAL 8.0 MAGNITUDE EARTHQUAKE IN KANGRA REGION OF HIMACHAL PRADESH

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INTRODUCTION

The state of Himachal Pradesh is located between 30.3^{0} - 33.0^{0} N latitude and 75.6^{0} - 79.0^{0} E longitude in the western Himalayas. Seismically it lies in the great Alpide-Himalayan seismic belt running from Alps mountains through Yugoslavia, Turkey, Iran, Afghanistan, Pakistan, India, Nepal, Bhutan and Burma. The terrain is hilly all through the state of Himachal Pradesh, the ranges varying from the Shivaliks in the south to the tall snow clad Pir Panjals in the north. These are traversed by major rivers, Sutlej and Beas and their tributeries. The state has not only been shaken by earthquakes occurring in its territory but also in the neighbouring areas of Jammu and Kashmir in the north, Tibet in the east and U.P. Hills in the south-east. A number of damaging earthquakes have occurred in the H.P. territory during this century for which information is well recorded. Information about earthquake occurrence before the famous 1905 Kangra earthquake is not, however, available and is a matter of research through historical and archival records. The aim of this paper is to present a profile of the seismic hazard in the state, the types of prevalent construction, their vulnerability to the earthquake hazards and the resulting seismic risk from a hypothetical earthquake of Magnitude 8.0 on Richter scale, if it were to occur now in the same area in which as large an earthquake had occurred in 1905. In view of the high seismic risk existing in the state, major earthquake disaster mitigation effort is called for. The important activity components for earthquake disaster reduction are also discussed with relevance to the state of Himachal Pradesh.

THE EARTHQUAKE OCCURRENCE IN H.P.

The earthquake activity in H.P is attributed to the Himalayan orogeny. Based on the latest concept of plate tectonic model of the earth, the Himalayan mountains have formed due to continuous thrusting of the Indian plate with Eurasian plate since Cretaceous times. The present geological structure and the tectonic of the Himalayas have been formed as a result of this continued collision. There are regional tectonic features in Himalayas like the Main Boundary Fault (MBF) and Main Central Thrust (MCT) running parallel to the strike length of Himalayas. Apart from these regional tectonic features there are lineaments running transverse to the Himalayan trend. Slow movements result in the elastic strain build up and the sudden release of tectonic strain energy along any of these tectonic features causes the observed earhtquake activity.

The region surrounding Dharmsala and Kangra is the seat of great Kangra earthquake of 1905 (M=8.0 on Richter's magnitude scale) and is having historically high seismicity. The region falls in seismic zone V of the seismic zoning map of India which is based on probable intensity IX and more on Modified Mercalli 'MM' scale. Fig. 1 gives the epicentres of earthquakes observed upto 1988. There are 250 earthquakes of Magnitude 4.0 and more including 81 earthquakes with magnitude above 5.0 which have rocked the state of H.P. and adjoining regions of Jammu & Kashmir in the last eighty five years.

Among these earthquakes three earthquakes have caused considerable damage and loss of life. These are briefly described herebelow:

Damage Due to Great Kangra Earthquake of 1905

This earthquake having a magnitude 8.0 on Richter scale had its epicentre at 32^o 15'N, 76^o 15'E and occurred at ooh 50m GMT or 06h 20m IST. It had taken a toll of 20,000 lives, caused MM intensity X and more in the epicentral region and was felt over an area of 416000 sq. km. It was concluded that the earthquake may have been caused due to a displacement taking place along a low angle fault at a depth of 34 to 64km. The Isoseismals of this earthquake on Rossi-Forrel intensity scale as observed and MM scale as interpolated are shown in Fig. 2.

Moving from pathankot towards Dharmsala, the first violent effect of this earthquake was observed at Shahpur at a distance of 55 km. The shops at the road side built in sun-dried bricks with heavy state roofs were partly ruined (roof collapsed, but walls standing). At Shahpur, half the buildings were ruined and rest were rent apart. All buildings were built of roughly shaped sun-dried bricks and sometimes with stone foundations raised about 15 cm above ground. Roofs were normally of slates but sometime thatch was also used.

Beyond Shahpur in the direction of Dharamsala and Kangra the damage was of ascending scale. The route between Shahpur and Dharamsala showed intense damage to the small and big villages and lines of communication. The road was broken at many places. At village Cheri the effect was maximum and the whole village was destroyed with the exception of only one or two stronger buildings which were also half ruined. Generally speaking the houses had become mere heaps of sun-dried bricks, mixed with slates and rafters.

The Dharamsala township suffered severe damage amounting to total destruction at many places and casualties reached very high figure. The military and civil staff was reduced to about one-half by deaths. The barracks at the cantonment consisted of long single storey buildings, the principal walls being built of sun-dried bricks and the two end walls of cut stones. The roofs were of thick slates. In all cases, the two long walls had rocked over generally as a whole in the downhill direction with the exception of the portions immediately connected with the stone walls at the gable ends. Buildings built throughout of dressed stone were badly cracked and rent and the portions like gable ends had been flung out as a whole flat on to the ground. The iron framed roof with two rods across from wall to wall preserved the Armory building from complete collapse. The Magazine consisting of a central square room, very strongly built of well dressed stones and lime mortar with arched roof showed only crakcs.

At Forsythganj bazar, buildings were constructed of sun-dried bricks especially in the lower storeys and partly of wood mostly in the upper storeys and verandahs. All shops to the east of the road were ruined while on the west many of them survived total collapse.

Mcleodganj bazar was levelled to the ground with no building standing even partially. Same was the situation at Kotwali bazar which reduced to a thick deposit of house rubbish about 1.5m high through which roads and lanes were cut for rescue and salvage operation. At Kangra the devastation was total. Not a signle house was standing. The horror of the actual calamity was beyond imagination. There was no one left alive for directing rescue operations. All the subordinate officials were killed and panic stricken people fled fearing that yet worse terrors would envelope them.

After the earthquake, the district headquarters were shifted to Dharmsala which was rebuilt using wood-framed brick-nogged buildings locally called, Dajji, the present office and residence of the Deputy Commissioner there being the existing examples of this construction. This appears to have become the typical construction then, even being used by private people for their shops and houses. But later on gradually and more particularly after independence of the country when pace of development became fast and wood started becoming scarce, this very highly earthquake resistant construction method, namely Dajji, was superceded by plains type brick and hill-type stone constructions. Their unsuitability for meeting the earthquake shaking became clearly manifest in April 26, 1986 earthquake of M=5.7 and slightly obvious during the earlier quake of 15 June 1978 with M=5.0 occurring in the same general epicentral region.

Dharmsala Earthquake of April 26, 1986

The epicentre of this earthquake of M=5.7 was at Lat. 32.1°N and Long. 76.3°E, that is, very close to that of 1905 earthquake. The origin time was 13h 5m 17s Indian Standard Time and focal depth was shallow, about 10km. The loss of life was fortunately small, only about 6 persons, since the earthquake did not last long, although a very large number of dwellings got cracked including many government buildings at Dharmsala and other towns. Most significant damage, requiring reconstruction of houses, was to adobe and stone house in the villages near Dharmsala, such as Narghota, Naddi, Kaned, Sukar and Khanyara. The total financial loss was estimated as Rs. 65 crores according to newspaper reports.

In comparison to Kangra earthquake of 1905, Dharmsala earthquake had a destructive energy of only about 1/28000. The maximum Modified Mercalli intensities in the two earthquakes were XI and VII^{+} respectively showing again that the 1986 quake was rather a minor one as compared to the giant earthquake of 1905.

Kinnaur Earthquake of Jan. 19, 1975

The Richter magnitude was estimated as 6.7 and maximum observed intensity in the region was IX of MM scale. The expicentral distance was about 25 km from Kinnaur town. The earthquake caused death of sixty people and several hundred were severely injured. Traditional construction in the area was non-seismic and had little resistance against the lateral forces. Nearly 2000 dwellings are reported to have suffered heavy damage, (SINGH, et. al, 1975) even in that sparsely populated area.

Recent random rubble masonry and dressed stone masonry construction suffered extensive damage. Heavy flat roofs suffered greater damage. Buildings constructed in hollow concrete blocks or dressed stone masonry in cement-mortar developed small cracks in walls. Light structures made of corrugated iron sheets nailed to timber frames and arches did not suffer any damage. The temples (monastries) and monuments also suffered badly.

BUILDING CONSTRUCTION IN H.P.

The building construction in Himachal Pradesh, except for the newer R.C. framed buildings in larger towns, follows the traditional pattern of load bearing walls in burnt bricks, stone or unburnt clay blocks (called 'Adobe' construction in modern writings) with sloping roofs in high rainfall areas and flat roofs in the dry areas. A very good idea of the house construction in the whole state may be obtained with reference to 1971 Census of Houses, the main data from which is presented in Table 1. The Census houses include dwellings, residences, shop cum residences, workshops cum residences, hotels, sarais, dharmsalas, tourist houses, inspection houses, business houses and offices restaurant, sweet shops and eating places; cinemas and panchayat ghhars, places of worship and those lying vacant.

Table 1. Predominant Material used in Houses in Himachal Pradesh (Census of India, 1971)

Wall or Roof	Predominant Material used	% of Total (No. of houses = 862896	% of Urban areas (No. of Urban Hourse = 80551	% of Rural areas (No. of Rural houses = 782,345	% in Seismic Zone V and Parts of IV (No. of houses = 599816
	Mud	17.32	6.62	18.42	18.74
	Unbrunt Brick	21.87	7.83	23.31	31.21
Wall	Wood	1.41	2.92	1.26	1.12
	Burnt Brick	6.15	32.15	3.48	5.25
	Stone	51.78	40.33	52.93	42.41
	Cement Concrete	1.00	9.33	0.14	0.99
	Unspecified	0.47	0.82	0.46	0.28
	Thatch, leaves, reeds etc.	30.18	15.58	31.69	28.36
	Tile, Slate, Shingle	54.59	20.12	58.15	61.42
Roof	C.G.I./Metal Sheet	9.46	33.86	6.95	6.83
	A.C. Sheet	1.25	6.98	0.66	1.57
	Brick and Lime	0.44	1.69	0.31	0.49
	Stone	1.22	3.47	0.99	0.66
	Concrete, R.B.C., R.C.	2.75	17.87	1.19	1.55
	Others	0.11	0.43	0.06	0.12

*Districts of Chamba, Kangra, Mandi, Kulu and Hamirpur have seismic zones V and IV, the remaining districts have only seismic zone IV.

From Table 1 it is clearly seen that the predominant materials used in walls are: mud and Adobe 39%, stone 52% and bricks 6%. All these are highly vulnerable to damage in seismic intensities MM VIII and IX which form the basis of seismic zones IV and V respectively. Wood and concrete walls which are rather safe in moderate earthquakes constitute only about 2.4% of the total housing.

The predominant materials used in the roofs are thatch and reeds etc 30%, and tile, slate and shingle 54.6%. Thatch when wet and the tiled roofs tend to be heavy and cause large earthquake forces on the structure without providing the binding effect on the walls, therefore, unsuitable for seismic zones IV and V. Metal and A.C. sheet roofs which are light in weight and the concrete slab roof which have a binding effect on the walls, are both suitable from seismic angle.

Five districts of Himachal Pradesh namely Chamba, Kangra, Mandi, Kulu and Hamirpur which have parts of their areas in seismic zone V and Parts in zone IV have higher seismic hazard than the other districts which have only seismic zone IV. The situation of housing in these five districts in also presented in the last column of Table 1. It is seen that the predominant construction materials in houses in these districts are: mud and Adobe 50%, stone 42.4% and burnt brick 5.3%. The seismic vulnerability situation here is more grave than the State as a whole since here the probable maximum intensity is MM IX or more in seismic zone V. For ready reference the M.S.K. intensities VIII and IX as related to building damage are stated in Table 2 (see IS:1893-1984).

Table 2 Seismic Intensity and Maximum Damage to Buildings

Building Type	Intensity VII	Intensity VIII	Intensity IX
(i) Reinforced buildings, well built wooden buildings	Many have fine plaster cracks	Most may have small cracks in walls, Few may have large deep cracks	Many may have large and deep cracks, Few may have partial collapses.
(ii) Ordinary brick buildings, building of large blocks and prefab type, poor half timbered houses	Many have small cracks in walls	Most have large and deep cracks	Many show partial collapse Few completely collapse
(iii) Mud and Adobe houses, random-stone constructions	Most have large deep cracks Few suffer partial collapse	Most suffer partial collapse	Most suffer complete collapse

*Most = about 75%, Many = about 50%, Few = about 5%

DAMAGE POTENTIAL OF MAGNITUDE 8.0 EARTHQUAKE:

The damage potential of an earthquake of magnitude 8.0 on Richter scale to the housing buildings in Kangra region can best the estimated by referring to what happened during 1905 earthquake in that region and the type and numbers of housing today. To arrive at a reasonable estimate of the potential damages, a number of plausible assumptions have to be made. These are listed herebelow:

1. It will be reasonable to assumed that the size of various intensity zones will be the same as that in 1905 earthquake.

2. Since the building pattern has not substancially changed since 1905, as evidenced by the materials of construction in Table 1 as per 1971 census, the damage pattern can be assumed as in 1905 earthquake which will be as globally averaged in the MM Intensity scale (see Table 2).

For using the average figures of Table 2 in quantitative estimate of damages to buildings, the intensities on Rossi-Forrel scale shown in Fig. 2 have to be interpretted in terms of MM scale. For this purpose the following equivalence is used (Richter 1958).

M.M. I	II	III	IV	V	VI	VII	VIII	X	X-XII
R.F. I	I-II	III	IV-V	V-VI	VI-VII	$VIII^-$	$VIII^+$ to IX^-	IX^+	X

Using this equivalence, MMX, IX and VIII isoseismals are interpolated and shown by dashed curves in Fig. 2. Measuring the areas covered by various intensity effects, the following figures are obtained.

MM X and more	500 Km^2	These areas lie wholly
MM IX	2400 "	in Himachal Pradesh
MM VIII	5000 "	
MM VII (not shown)	26000 "	There areas lie in H.P. as well as in neighbour states

Figure 2 shows the present districts, viz. Chamba, Kangra, Mandi, Kulu and Hamirpur in which damaging intensities leading to collapse of houses, that is, X, IX and VIII occurred. Damage also occurred in Intensity VII zone also but not collapses or loss of life.

It is further assumed that the population in the affected districts has the same density within Isoseismal VIII and outside it. Hence the number of total census houses lying within Isoseismal VIII can approximately be estimated by proportioning the areas under the isoseismals to the total area of districts. Using a total area of the five districts as 18000 Km^2, the total number of houses within isoseismal VIII is estimated as 378700 by proportion to total number of houses (1971 Census) in the districts viz. 862896.

Further assuming the population (hence house numbers) increase to be 2 percent per annum, the total number of houses at present (1989) will be 40% more, that is, 530,000. Further calculations of estimated effects of M=8.0 earthquake are based on the total number of houses as 530000 within Isoseismal VIII.

Referring to Table 2, three building types are defined for quantitative damage estimation in different intensities areas. From Table 1, the percentage of these buildings in the five districts of concern is obtained as follows:

Concrete and wood buildings	1.12 + 0.99	= 2.11%
Ordinary brick buildings		= 5.25%
Mud, Adobe and stone buildings	18.74+31.21+42.41	= 92.36%

It is also seen that out of 42.41% stone buildings, 3.92% are in urban areas and 38.49% in rural areas. It is assumed that 50% of the urban buildings will be of better quality dressed stone type which should behave like brick buildings during earthqukes. Also during the period 1971-1989, there may be some increase in better quality concrete and brick buildings. For purposes of estimating damage potential, the following percentages are assumed:

Concrete and wood buildings = 2.5%

Ordinary brick and Good stone buildings = 9.0%

Mud, Adobe and field stone buildings = 88.0%

The potential damage to buildings is estimated in Table 3 with the help of Table 2 based on SK. Scale.

Table 3. Estimate of Potential Building Damage
(Total houses 530,000 7900 Km²)

Building Type	No. of Houses in each Intensity zone		No. of Houses to sustain damage								No Damage
			(a) Comlete Collapse		(b) Part Destruct		(C)Large Cracks		(d)Minor Cracks		
A.Mud, Adobe, field stone	X	29500	Most	22125	Bal	7375	-	-		-	-
	IX	141700	Most	106275	Bal	28340	Few	7085		-	-
	VIII	295200	Few	14760	Most	221400	Bal	44280	Few	14760	-
B.Ordin.	X	3000	Many	1500	Bal	1350	Few	150		-	-
	IX	14500	Few	750	Many	7250	Bal	5800	Few	725	-
	VIII	30200	-		Few	1510	Many	15100	Bal	13590	-
C.Concrete and wood	X	800	Few	40	Many	400	Bal	360	• -		-
	IX	4000	-	-	Few	200	Many	2000	Bal	1800	-
	VIII	8400	-	-	-	-	Few	420	Most	6300	1680
Total		527300		145425		267825		75195		37175	168

*Rounded to nearest hundred

Few = 5%, Many = 50%, Most = 75%, Bal = balance out of total

In Table 3 the last time sums up number of buildings with different degree of damage as described below:

(a) Completed collapsed houses

(b) Those pastly destroyed and pastly having large and deep cracks which will require reconstruction.

(c) Those without total or partial collapse but with large cracks, some of these may may have to be reconstructed but most repairable with 15 to 30% of the cost of reconstruction.

(d) Those with minor cracks or minor damage which most people will repair superficially and architecturally like replastering, white washing etc., the cost of which may be less than 2% of the building cost.

Potential of Life and Economic: Losses

For estimating potential loss of lives a number of assumption have to be made as follows:

a) The family size per house is assumed as five.

b) In the 1905 earthquake some actual statistics of killed and injured are given for Dharmsala army quarters which were of type B in Table 3. Out of a total of 669 persons, 286 were killed, 110 seriously injured and 261 slightly injured, rest remained unhurt. Description shows how bravely the ones who escaped injury and those slightly injured struggled to save lives from under the fallen debris otherwise deaths would have been many more. The time of earthquake was 6.20 AM in the month of April when it is not so cold. It is also stated that in Kangra and Palampur Tehsils above 13000 persons were killed amounting to about 1/10th of the population of these Tehsils.

It seems not so unreasonable to assume the death rates and total deaths as shown in Table 4.

Table 4. Assumed death rates and potential deaths

Time of occurrence	Deaths in collapsed Houses	Deaths in part collapsed houses	Total potential deaths
Midnight-sleeping	40%	20%	344000
Mornings (awake and sleeping)	20%	10%	177000
Noon time (out working)	10%	5%	88000

The number of potential deaths shown in Table 4 would also vary with the month of the year of the potential earthquake occurrence, being more for winter and less for summer. Collapses of houses will be comparatively much more if the earthquake would occur in the monsoon season when the mud used in houses becomes soft and weak.

It is difficult to estimate the total economic losses which not only occur due to collapse or damage to houses in intensities X, IX and VIII but also in Intensity VII which had a very large coverage of 26000 km^2. The damage cost to H.P. in April 26, 1986 earthquake of Mag. 5.7 only was reported as Rs. 66.0 crores, when maximum intensity was VII. It is not unreasonable to assume that the damage to buildings only may amount to a couple of thousand crores besides the cost of damage to bridges, water towers, industries, water supply lines etc.

EARTHQUAKE DISASTER MITIGATION POLICY

It is said that nature causes a hazard, man converts it into a disaster to himself. It is seen that earthquake occurrence is a natural phenomenon on which man has no control. In fact, it occurs suddenly without warning for which a reliable prediction is not yet possible. Even if a short range prediction of location, magnitude and time of occurrence of an earthquake becomes possible some time in future, it may only be used to save human lives but not his hearth or home for which an engineering solution is a must and which can not be done at short notice. Therefore the real approach to earthquake disaster reduction lies in preventive actions before the future event. Knowledge has sufficiently advanced to permit not-too-expensive earthquake-resistant constructions.

Studies of natural disasters by UNDRO have conclusively revealed that most natural disasters can be mitigated/reduced by preventive actions and that the most basic preventive measures are the least expensive too. To exemplify the last statement; to make a brick house collapse-proof in the area affected by hypothetical 8.0 Mag. earthquake in the Kangra region, it will require 4 to 6% extra expense if the earthquake resistingmeasures were built in a brick or stone house in the first instance during construction stage which will effectivey prevent its collapse and reduce the damage to cracking stage only. But it may require 15 to 25% extra cost if it is seismically retrofitted after construction is completed. If nothing is done at any time for earthquake resistance, the house may have to be reconstructed altogether after an intensity IX earthquake occurs which may also kill many of the inmates of the house.

CONCLUSIONS

The following main conclusions can be drawn from the above presentation.

(i) Himachal Pradesh has a history of moderate to severe earthquake occurrences and its area is covered with seismic zones V and IV with possible maximum magnitudes upto 8.0 on Richter scale and MM intensities upto VIII in Zone IV and IX or more in Zone V.

(ii) The existing buildings are highly vulnerably to damage levels upto collapse in probable maximum earthquakes, being safe only in periods between two damaging earthquake occurrences. As per the estimates presented, a Mag. 8.0 earthquake could cause complete collapse of 145000 houses and partial collapse of 268000 houses in an area of 7900 km^2. The loss of lives could range from 88000 to 344000 depending on the time of the day and the season when it occurs. This calls for an urgent concerted planning and action to retrofit existing important buildings inZone V to start with and provision of earthquake resistant features in all new buildings in urban as well as rural areas.

(iii) Earthquake disaster reduction is a distinct possibility by careful preventive engineering measures which require only minor extra expenditure to what is required for normal construction.

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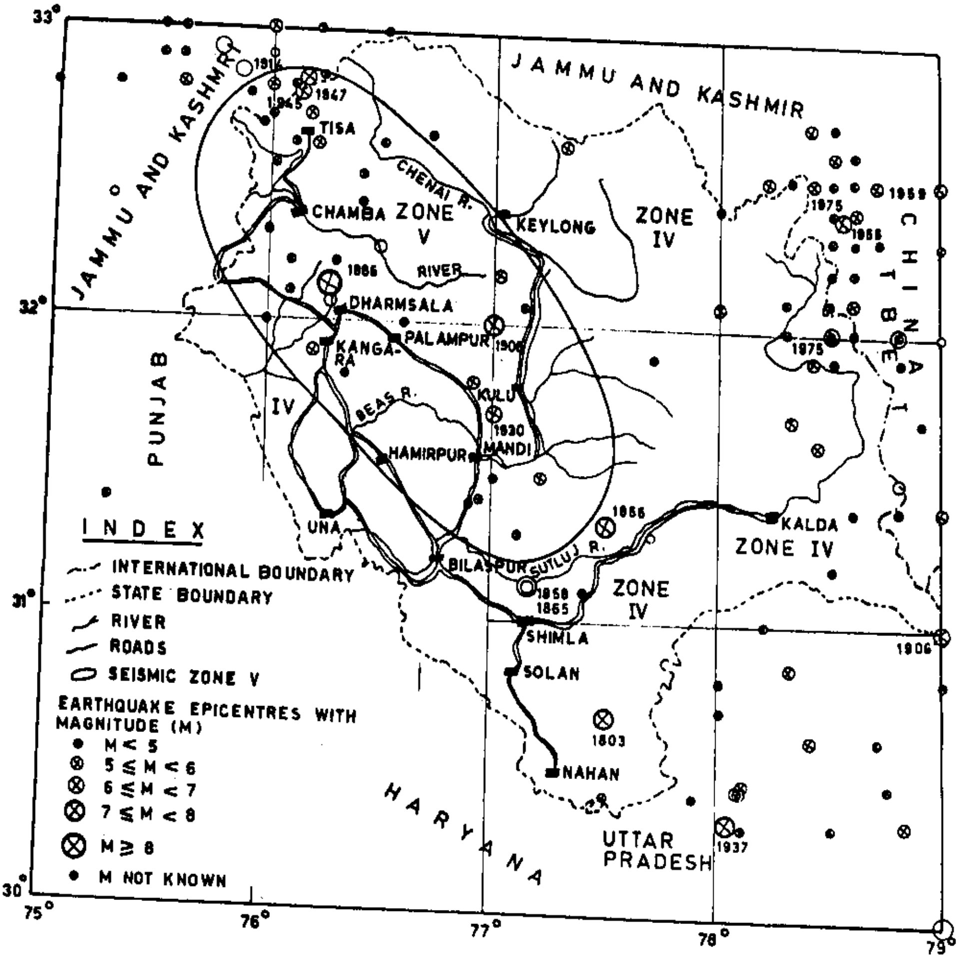

FIG.1 - MAP OF HIMACHAL PRADESH SHOWING EARTHQUAKE EPICENTERS UPTO 1988 AND SEISMIC ZONES AS PER IS 1893 - 1984

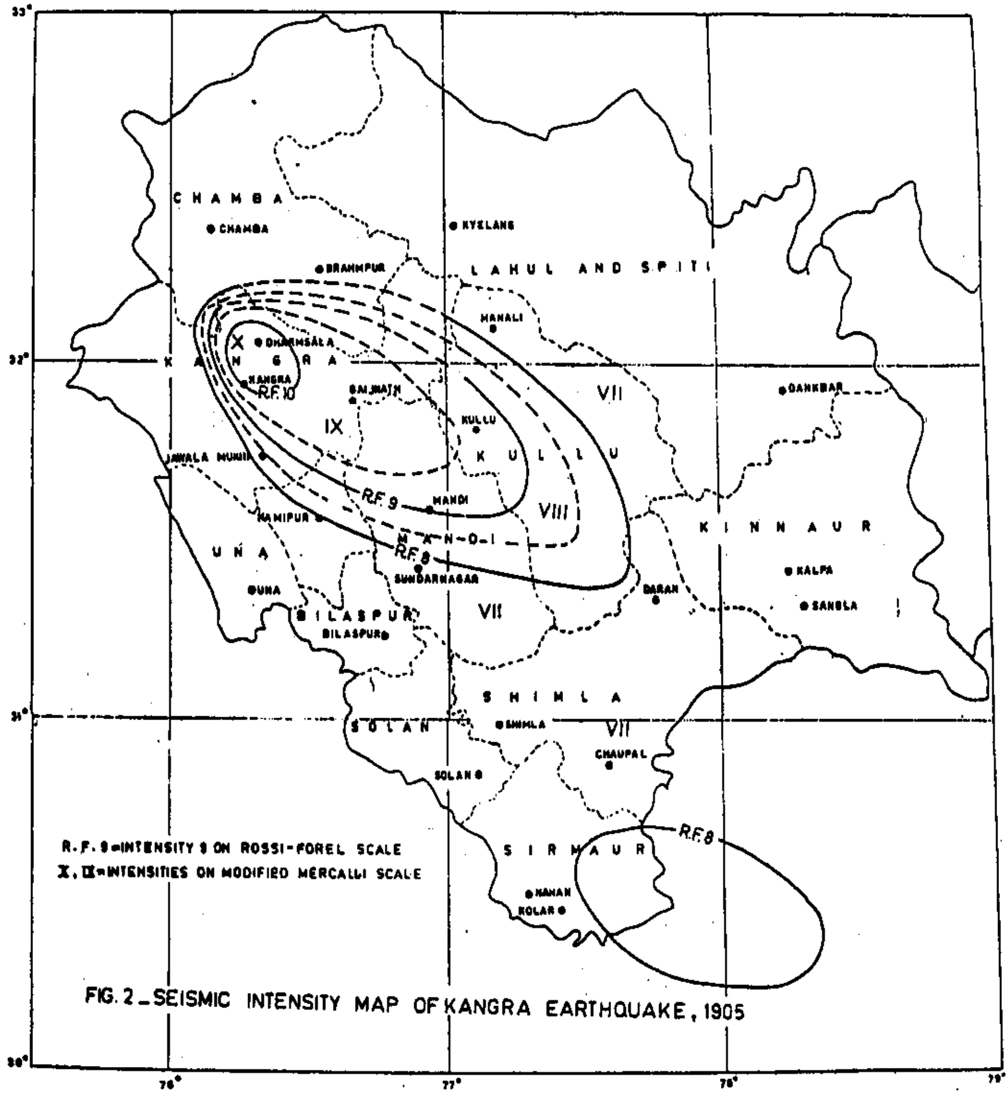

FIG. 2_SEISMIC INTENSITY MAP OF KANGRA EARTHQUAKE, 1905