POSSIBLE EFFECTS OF A MAJOR EARTHQUAKE IN KANGRA REGION OF HIMACHAL PRADESH

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ABSTRACT—*A major earthquake of magnitude 8.0 had caused severe catastrophe in Kangra region of Himachal Pradesh (H.P.) in April 1905 in which 20000 people were killed. It is dreadful to think what would happen if that kind of earthquake recurs now. Based on earthquake intensity distribution resulting from such an earthquake, the types and numbers of houses and the population density, this paper estimates the number of houses that could collapse, be destroyed and cracked and the possible numbers of human lives which may be lost. The approach to mitigate these effects by timely preventive actions is also outlined.*

INTRODUCTION

The state of Himachal Pradesh is located between 30.3°–33.0° N latitude and 75.6°–79.0° E longitude in the western Himalayas. Seismically it lies in the great Alpide-Himalayan seismic belt. The terrain is hilly all over the state, 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, Beas and their tributaries. The state has not only been shaken by earthquakes occurring in its territory but also those 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. The aim of this brief 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 as 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 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 tectonics 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 the regional 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 earthquake 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 zone V of the seismic zoning map of India which is based on probable intensity IX and more on Modified Mercalli 'MM' scale. Figure 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 and Kashmir in the last ninety years.

The great Kangra earthquake had its epicentre at 32° 15'N, 76° 15'E and occurred at 00h 50m GMT or 06h 20m IST on April 4, 1905. It had taken a toll of 20,000

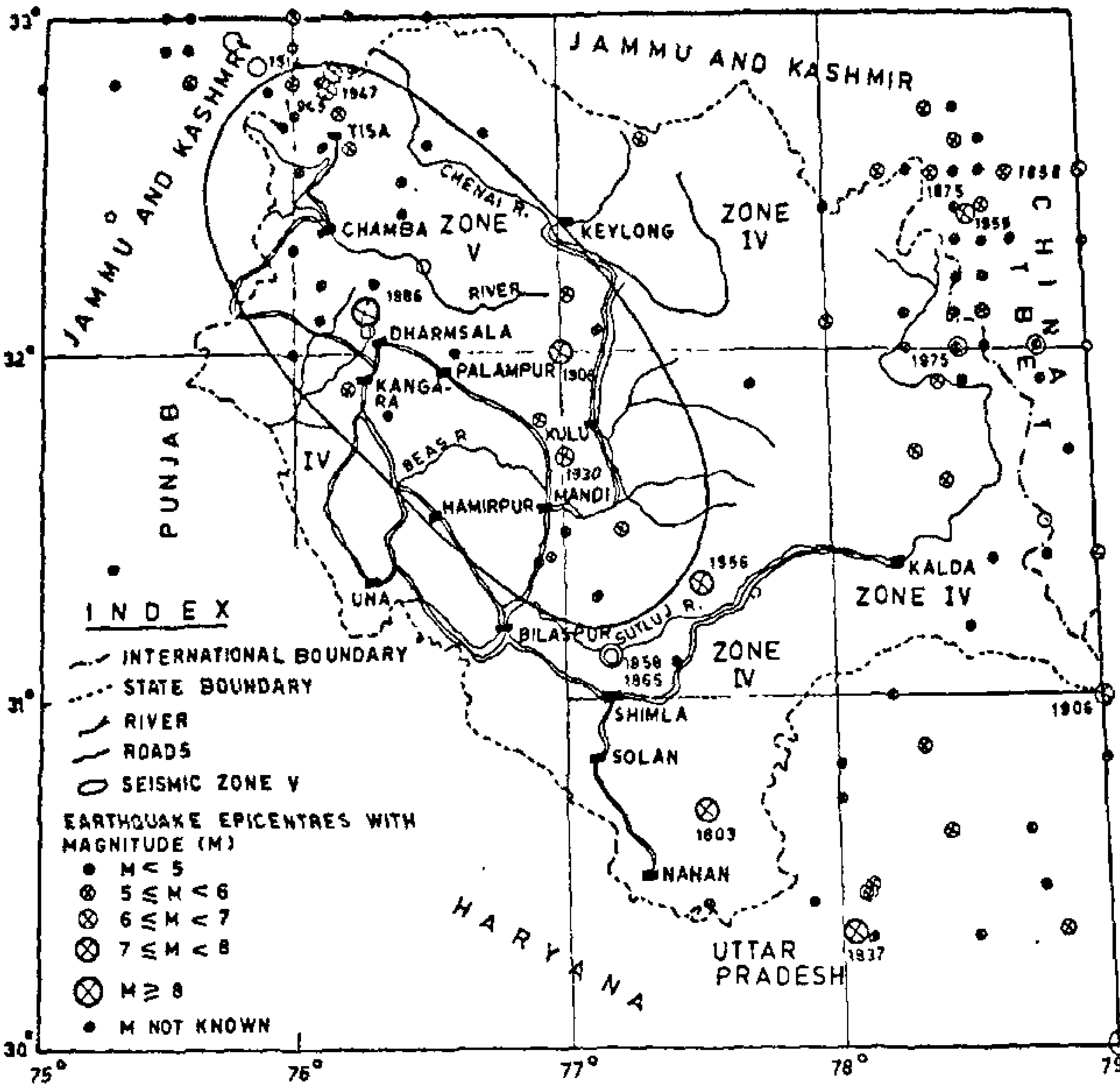

FIGURE 1 Map of Himachal Pradesh showing earthquake epicenters upto 1988 and seismic zones as per IS 1893–1984.

lives, caused MM intensity X and more in the epicentral region and was severely 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 64 km. The Isoseismals of this earthquake on Rossi-Forrel intensity scale as observed and MM scale as interpolated according to Richter's equivalence (1958) are shown in Figure 2. In this earthquake the devastation was total at Kangra. Not a single 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 shocks may envelope them. The same situation occurred in many towns and villages lying in MM IX area.

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 type 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 resisting the earthquake became clearly manifest in the April 26, 1986 earthquake of $M = 5.7$ when 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 houses in the villages near Dharmsala, such as Narghota, Naddi, Kaned, Sukar and Khanyara. The total financial loss was estimated as Rs. 65 crores in 1986 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

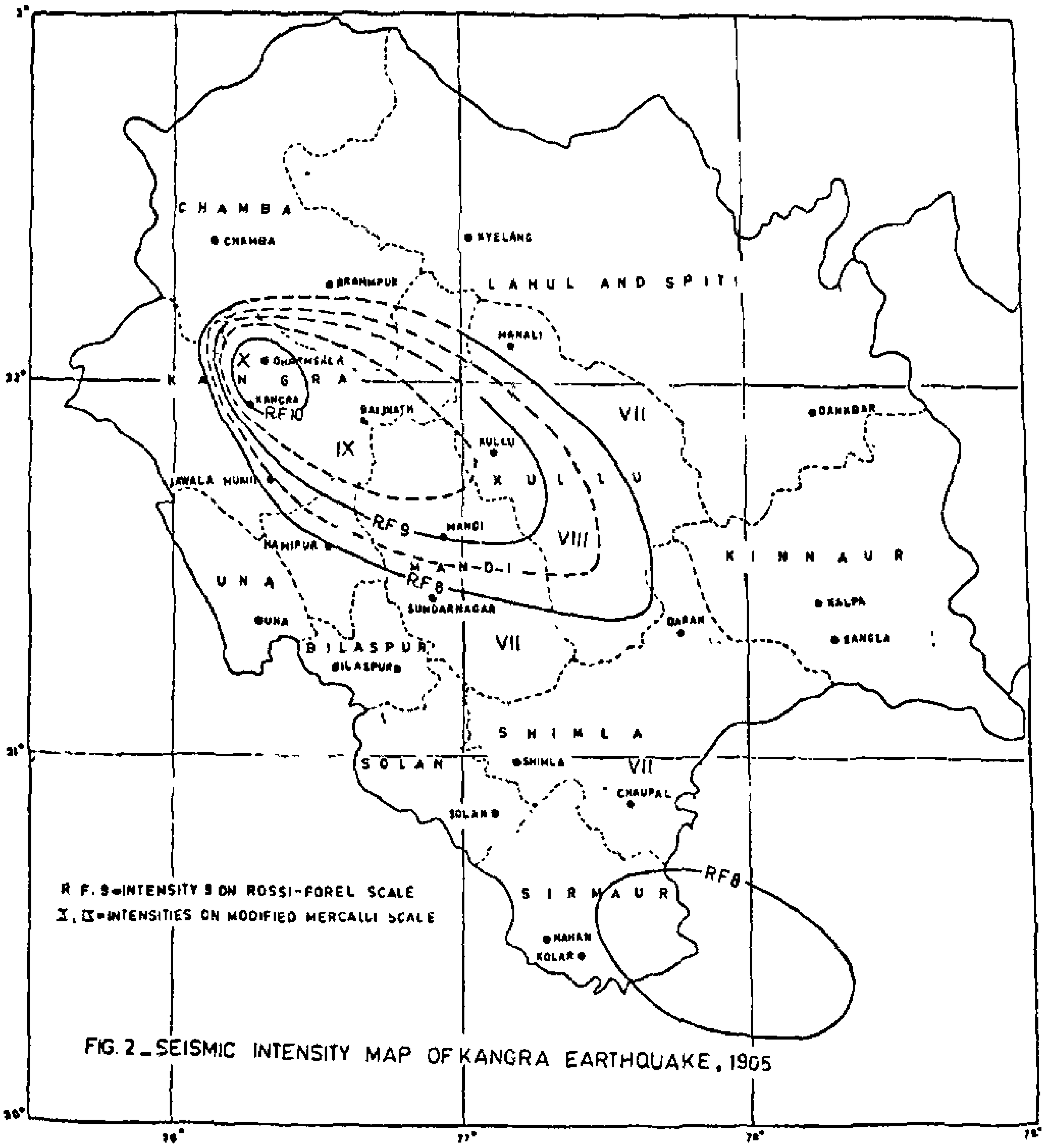

Figure 2 Seismic intensity map of Kangra Earthquake, 1905.

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.

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. It is 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 the seismic angle. Table 1 shows *the likely damage to different types of* buildings in MM VII, VIII and IX intensities[3].

TABLE 1. Seismic Intensity and Maximum Damage to Buildings.

Building type	Intensity VII	Intensity VIII	Intensity IX
1. 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.
2. 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* complete collapse.
3. 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 be estimated by referring to what happened during the 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 below:

- It will be reasonable to assume that the size of various intensity zones will be the same as that in 1905 earthquake.
- Since the building pattern has not substantially changed since 1905, as evidenced by the materials of construction 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 1).

Measuring the areas covered by various intensity effects in figure 2, it is found that 500 km^2 area will be in MM X or more, 2400 km^2 in MM IX, 5000 km^2 in MM VIII, wholly in Himachal Pradesh. Besides an area of 26000 km^2 will be under MM VII, partly in H.P. and partly in neighbouring states.

- It is further assumed that the population in the affected districts namely Chamba, Kangra, Mandi, Hamirpur and Kullu, 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 (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.

Now three building types are defined for quantitative damage estimation in different intensities areas. The percentage of these buildings in the five districts of concern is obtained as[2]: Concrete and wood buildings = 2.11%; Ordinary brick buildings = 5.25%, Mud, Adobe and stone buildings = 92.36%.

It is assumed that 50% of the urban buildings will be of better quality dressed stone type which should behave like brick buildings during earthquakes. 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 percentages assumed are: 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 can now be estimated with the help of table 1. Carrying out this exercise[2], the building damage is estimated as follows:

- Completely collapsed houses = 145400.
- Partly destroyed and partly severely damaged requiring reconstruction = 267800.
- Standing with large cracks (some to be reconstructed but mostly repairable with 15 to 30% of the cost of reconstruction) = 75200.

For estimating potential loss of lives the family size per house is assumed as five. In the 1905 earthquake some actual statistics of killed and injured are given for Dharmsala army quarters which were of ordinary brick or good-stone types. The time of earthquake was 6.20 AM in the month of April when it was not so cold. It is also stated that in Kangra and Palampur Tensils above 13000 persons were killed amounting to about 1/10th of the population of

TABLE 2. 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
Morning (awake and sleeping)	20%	10%	177000
Noon time (out working)	10%	5%	88000

these Tensils. Therefore it will not be unreasonable to assume the death rates and total deaths as shown in table 2.

The number of potential deaths shown in table 2 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 the April 26, 1986 earthquake of mag. 5.7 alone was reported as Rs. 65.0 crores, when maximum intensity was VII. It is not unreasonable to assume that the damage to buildings alone may amount to several thousand crores besides the cost of damage to bridges, water towers, industries, water supply lines, etc.

EARTHQUAKE DISASTER MITIGATION POLICY

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 a hypothetical 8.0 mag. earthquake in the Kangra region, it will require 4 to 6% extra expense *if the earthquake* resisting measures were built-in in *the first instance* during construction stage which will effectively 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:

- 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.
- The existing buildings are highly vulnerable 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 day and the season when it occurs. This calls for *urgent concerted planning and action to retrofit* existing important buildings in Zone V to start with and provision of earthquake resistant features in all new buildings in urban as well as rural areas.
- 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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