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Natural Disasters and Risk Assessment in Uttarakhand with special reference to Uttarkashi Earthquake.

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Abstract: *Uttarkashi lies in the main Alpine Himalayan belt, one of the most earthquake prone regions of the world. Crustal instability in this belt is ascribed to the movement of the Indian plate towords the Eurasian plate at the rate of about 50mm per year. Besides several local faults, two prominent thrusts tending northwest to southeast, from the conspicuous tectonic features.*

The basic aim of the present work is taken just one more step to make cities safer before the next disaster strikes. Development of a mitigation plan in more economic and effective in a long run than providing an ad-hoc relief after the disaster.

The earthquake caused strong ground shaking over a large area with worst effects suffered in Uttarkashi Bhatwari region. Damage was observed in unreinforced masonry buildings as well as RC frame structures. Good construction performed much better than poor quality construction. The need for RC roof and gable bands in masonry buildings was clearly underlined by the performance of buildings at the ITBP campus at Mahidanda. There was enormous loss due to landslides and collapse of retaining walls. The failure of Gawana bridge needs to be studied. This may trigger revision of the Indian code.

The earth is continually evolving and undergoing changes. From our view point at the surface of the Earth, we observe and are affected by both surface processes and the external expression of the activity occurring deep within the earth. This activity may be very slow and take place over millions of years, as in the case of a major earthquake.

Much of the large scale earth movement is concentrated along faults or breaks in the earth's crust e.g. Himalayan belt of Uttarakhand when movement occurs suddenly along a fault; energy is released in the form of an earthquake.

Earthquake consists of vertical and horizontal waves like motions of the ground. The horizontal motions cause heavy destructive forces being larger than the vertical waves say 5 to 10 times greater. They may further be along any direction.

Aims And Objectives Of Present Work:

The basic aim of the present work is taken just one more step to make cities safer before the next disaster strikes. Development of a mitigation plan in more economic and effective in a long run than providing an ad-hoc relief after the disaster.

Table :1 District- wise House types as per MSK Classifcation

Name of District No. of Houses	Ares of District & houses (Per km^2)	Number of A,B,C type houses with percentage	Area under MSK Intensity KM^2	Number of houses in Intensity Area	Numbe r a type houses	Number B-type houses	Number of C type houses
Almora 282620	5385 (52.48)	A 273530 (96.78%) B 6515 (2.31%) C 2575 (0.91%)	VIII 800 VII 1300 VI 3285	41986 68228 177406	40636 66033 166861	968 1573 3974	382 622 1571
Chamoli 199745	9125 (21.89)	A 193635(96.94%) B 1250(0.63%) C 4860(20.43%)	VIII 800 VII 1300 VI 4600	17512 28457 100693	16976 27585 97613	110 178 630	426 692 2450
Dehradun 254985	3088 (82.57)	A 89940(35.27%) B 155055(60.81%) C 9990(3.92%)	VIII 800 VII 1300 VI 988	60058 107344 81582	23300 37863 28776	40170 65276 49609	2588 4207 3196

Garhwal 251535	5440 (46.24)	A 218335(86.80%) B 27855(11.08%) C 5345(2.12%)	VIII 800 VII 1300 VI 3340	36990 60109 154435	32108 52176 134051	4096 6657 17102	786 1277 3282
Nainital 333055	6794 (49.02)	A 138155(41.48%) B 179010(53.73%) C 15890(4.77%)	VIII 800 VII 1300 VI 4600	39218 63729 225501	16268 26435 93540	21079 34253 121202	1871 3040 10759
Pithoragarh 185620	8856 (20.96)	A 173655(93.55%) B 7945(4.28%) C 4020(2.17%)	VIII 800 VII 1300 VI 4600	16768 27248 96415	15687 25491 90200	718 1166 4127	363 590 2088
Tehri Garhwal 204655	4421 (46.29)	A 189870(92.78%) B 9060(4.43%) C 5725(2.79%)	VIII 800 VII 1300 VI 2321	37033 60179 107443	34358 55831 99681	1639 2664 4756	1036 1683 3006
Uttarkashi 88630	8016 (11.06)	A 70500(79.54%) B 5725(6.46%) C 12405(14.0%)	VIII 800 VII 1300 VI 4600	8845 14374 50860	7036 11433 40457	571 928 3285	1238 2012 7119

Note: Building Type

A. Mud and adobe houses, random stone constructions
B. Ordinary brick buildings, buildings of large blocks and Prefer type.
C. Reinforced building, well built wooden buildings

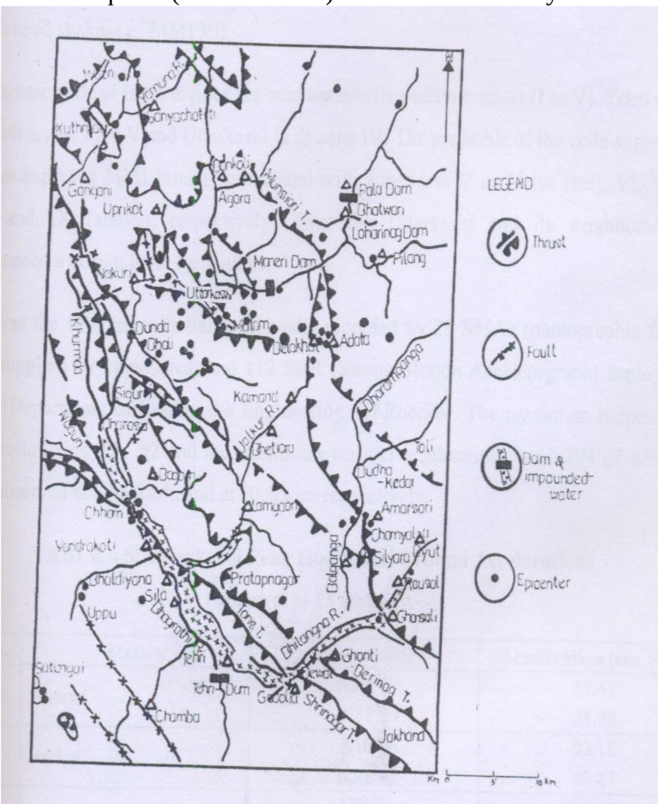
Sources; Arya, A.S; Damage scenarios of probable earthquake of M6.5 in UP, Himalaya, Himalyan Geology, Vol.20(1)

Uttarkashi Earthquake:

On October 20, 1991, at 2.53 a.m. local time, an earthquake occurred in the Garhwal Himalaya in northern India. The earthquake caused strong ground shaking in the district of Uttarkashi, Tehri and chamoli in the state of Uttarakhand.

Uttarkashi lies in the main Alpine Himalayan belt, one of the most earthquake prone regions of the world. Crustal instability in this belt is ascribed to the movement of the Indian plate towords the Eurasian plate at the rate of about 50mm per year. Besides several local faults, two prominent thrusts tending northwest to southeast, from the conspicuous tectonic features.

Figure: 1 Uttarkashi – Earthquake (October 1991) and Microseismicity in Tehri- Uttarkashi Region



Source : Valdiya, K.s.

This Earthquake has provided excellent strong motion records. The area is instrumented with a number of SMA's (Photo graphic film type, supplied by kinematics) and structural response recorders(SRR) operated by the university of Roorkee. Maximum horizontal acceleration of 0.03g and maximum Vertical acceleration of 0.04 g were recorded. .

INTENSITY OF SHAKING:

The intensity of shaking was moderate. The maximum intensity was VIII on the modified mercalli (MM) scale at Budhakedar, Krishanpur, Maneri, Uttarkashi, Mahinanda and Bhatwari, Tehri, Ghansyali and Gangotri had a shaking of MMI VII.

The seismic code in India, Tehri and chamoli are in zone V and Uttarkashi is in Zone IV. This was the first major Indian earthquake recorded by 28 SMAs(Photographic film type, supplied by kinematics) and 112 SRR (Strong Motion Accelerograph) deployed by the Department of Earthquake engineering, IIT Roorkee. The maximum horizontal acceleration was 0.31 g^2 and the maximum vertical acceleration was 0.294 g^2 which were observed at Uttarkashi and at Bhatwari respectively.

Table 2: Uttarkashi Peak Horizontal Groung Accelerations recorded at 13 stations.

Sr. No.	Station	Component	Acceleration(cm.sec^2)
1	Almora	N53^{0}W N37^{0}E	17.41 21.02
2	Barakot	N10^{0}E N80^{0}W	93.18 80.47
3	Bhatwari	N85^{0}E N05^{0}W	248.37 241.89
4	Ghansali	N00^{0}E N90^{0}E	115.59 114.89
5	Karnprayag	N05^{0}W N85^{0}E	60.99 77.35
6	Kosani	N25^{0}W N65^{0}E	28.34 31.50
7	Koteshewar	N30^{0}W N60^{0}E	98.85 65.23
8	Koti	N10^{0}E N80^{0}W	20.64 40.95
9	Purola	N65^{0}W N25^{0}E	73.95 91.68
10	Rudraprayag	N53^{0}E N37^{0}W	52.29 50.67
11	Srinagar	N50^{0}W N40^{0}E	65.44 49.44
12	Tehri	N65^{0}W N27^{0}E	71.41 61.13
13	Uttarkashi	N15^{0}W N75^{0}E	237.27 303.99

Source- Chandrasekran and Das, 1995

BUILDINGS DAMAGE:-

Damage to rural dwellings (random rubble stone masonry supporting a heavy root) was extensive in areas of maximum shaking. In developed areas, most privately owned buildings and older government owned buildings were build without seismic provisions.

Table – 3 Damages

District	Village Affected	Population Affected (in lacs)	Damage Houses		Lives lost		Injuries Persons
			Fully	Partially	Human	Cattles	
Uttarkashi	601	2.50	14847	19811	650	562	4710
Tehri Garhwal	605	1.00	4730	21954	63	71	43
Chamoli	699	0.72	573	1973	2	10	18

Dehradun	116	0.02	26	452	-	9	-
Pauri Garhwal	72	0.01	34	449	-	5	3
Nainital	-	-	2	4	-	-	-
Total	2093	4.25	20212	44643	715	657	4774

Source- Department of Revenue and Relif, U.P. Govt., 94

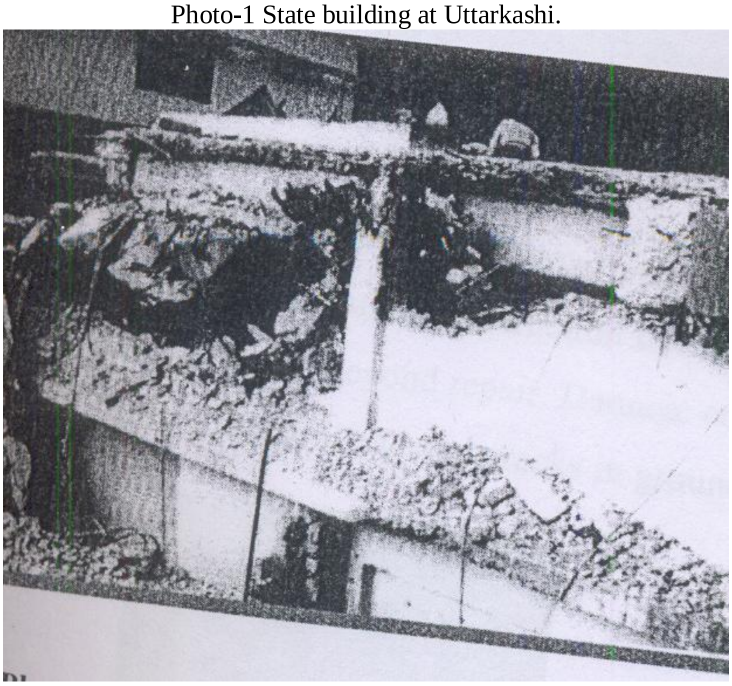
Table-4 Destruction caused by the Garhwal Oct. 20,1991

Affected Districts	Uttarkashi, Tehri, Rudraprayag and Chamoli
Persons killed	Around 800
Injured	5000 Approx
Affected villages	2000
Affected population	4.5 lakh
Totally Collapsed houses Semi collapsed with cracks	25000+
Useless for living	75000+
Collapsed School/ Inter colleges	630
Animals killed	4000+
Total Loss	Rs. 370 + Crores

Source- Himalaya Today Dec. 91-May 92

Uttarkashi has a number of three and four story reinforced concrete (RC) framed buildings which sustained damage. Photo(1) shows the state Bank building in Uttarkashi. During the earthquake, the upper two stories collapsed on the first story. Informations from the local residents revealed that the building was first constructed as one story only, the upper two stories were added subsequently. The beams has only two normal rebars on the top face near the column joint and those were incorrectly placed.

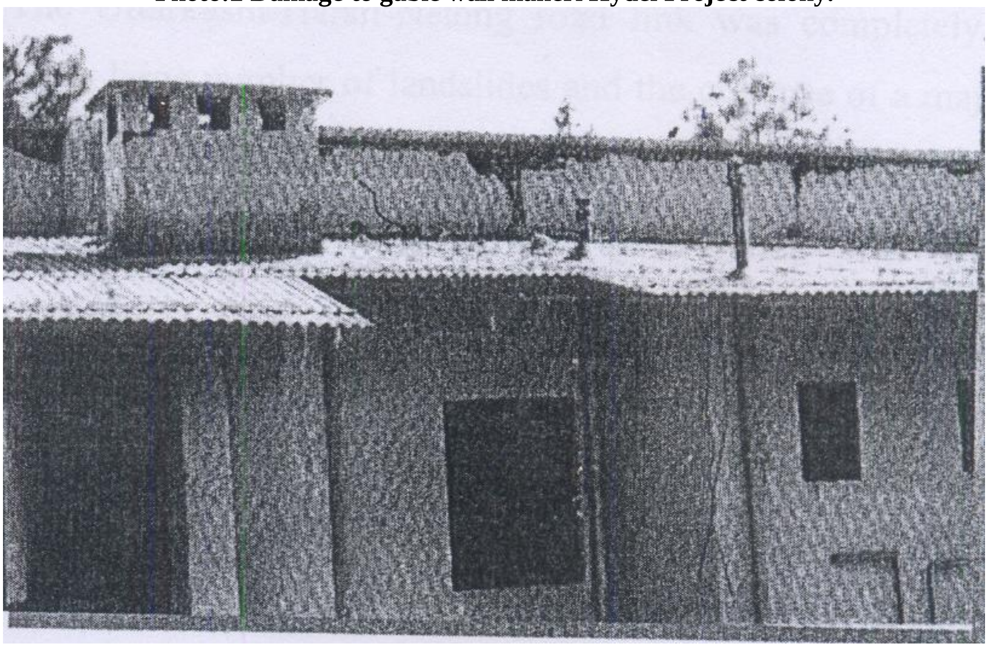
Photo-1 State building at Uttarkashi.



Most government buildings are one or two story buildings with load bearing walls and sloping roofs. Older construction is of unreinforced random rubble stone masonry which performed very poorly. The newer construction is of unreinforced concrete block masonry and usually include a RC band at lintel level.

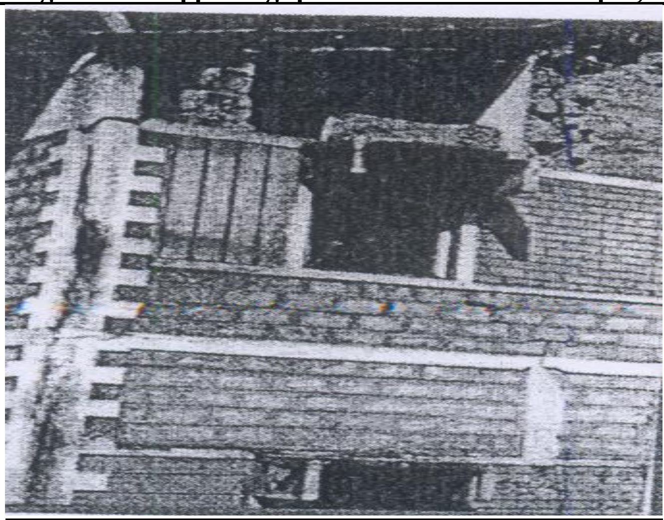
The Maneri Hydel Power project colony campus has two-storey buildings with concrete block masonry bearing walls of poorer quality construction. Many buildings were damaged beyond repair. Damage consisted of (I) severe damage to gable walls photo 2 and (ii) diagonal cracks in ground story walls.

Photo:2 Damage to gable wall maneri Hydel Project colony.



The ITBP Paramiliatry campus at Mahidanda consists a large number of two story residential buildings with load bearing walls of concerete masonry. All have RC lintel bands, but no roof bands or gable bands. The construction is about 10 years old . The damage to buildings consisted of (i) diagonal cracks below window sills, (ii) damage at the connection between masonry walls and RC roof slabs, (iii) in buildings with corrugated iron sheet roofs, damage at seat of purlings on the gable end walls and (iv) damage to walls supporting roofs at different heights at either end(Photo 3). Roof and gable bands would have prevented damage of types (ii), (iii) and (iv) .

Photo 3 Damage to wall supporting split level roof – ITBP Campus, Mahidanda.



DAMAGE ASSESSMENT OF ROADS:-

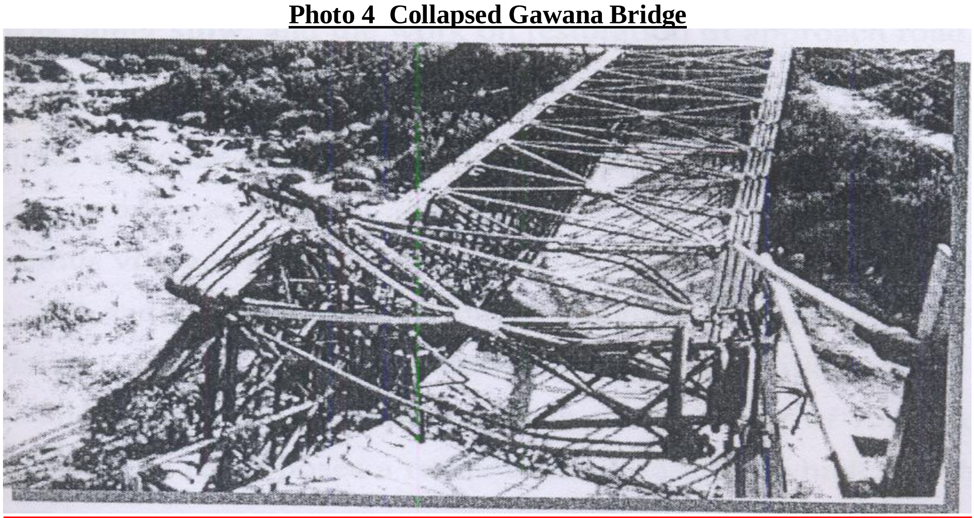
Roads in the area were extensively damaged due to failure of slopes, retaining walls, and bridges. The Uttarkashi Harsil Nelong road link was completely distrupted for several days due to large number of landslides and the collapse of a major bridge.

Numerous massive landslides took place on the Uttarkashi- Harsil road, particularly on a 42 km stretch between Uttarkashi and Bhatwari. The stretch is believed to be the area of most intense shaking.

On the Uttarkashi-Lumgaon route the approach road to a bridge near the village of Kishanpur is on an embankment about 8.0 m high with retaining walls in "banded" stone masonry. The walls on both sides of the approach road collapsed leading to failure of the embankment.

The Gawana Bridge is a 56.0m. span steel truss bridge build in 1974 and located at 6 Km. from Uttarkashi towards maneri. The entire bridge came off the abutments and fell into river (Photo 4) causing the entire area beyond Uttarkashi to be cut off from the rest of the country Inadequate design of the bearings and anchor bolts as well as absence of any suitable means of preventing the span from falling of the supports were responsible for the damage.

Photo 4 Collapsed Gawana Bridge



The area has a number of pedestrian suspension bridges that cross the river Bhagirathi. The main tower and the anchors blocks are of unreinforced stone masonry. Five of these bridges were damaged, four of them in the maneri Bhatwari region. Cracks in the tower and anchor blocks were typical of damage sustained.

The peak horizontal ground acceleration in the region was about 0.30 g. The Indian codes specifies the design seismic force for bridges in the range of 0.05 to 0.075 g for zone IV. This is obviously inadequate. It is hoped that the bridge failures caused by this earthquake will provide the necessary impetus to revise the code.

CONCLUSIONS:

The earthquake caused strong ground shaking over a large area with worst effects suffered in Uttarkashi Bhatwari region. Damage was observed in unreinforced masonry buildings as well as RC frame structures. Good construction performed much better than poor quality construction. The need for RC roof and gable bands in masonry buildings was clearly underlined by the performance of buildings at the ITBP campus at Mahidanda. There was enormous loss due to landslides and collapse of retaining walls. The failure of Gawana bridge needs to be studied. This may trigger revision of the Indian code.

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I take this opportunity of expressing my deep gratitude to my sisters, brother-in-laws, for their valuable assistance and moral support.

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