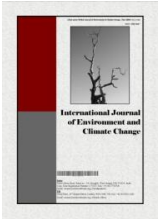

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Probing the Crisis of Regional Connectivity Instigated by the Natural Disasters, Mizoram, India

Siba Prasad Mishra[1*], Jyoti Prakash Puhan[1] and Saswat Mishra[2]

[1]Civil Engineering Department, Centurion University of technology & Management, Jatni, Bhubaneswar, India.
[2]Civil Engineering Department, KIIT University, Patia, Bhubaneswar, Odisa, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Mizoram, in eastern Himalayas of India, is educated but thinly populous young state of area 21081sq km with hilly forest cover of (≈90.68%) The major connectivity is by roads of length 8912km (2019) that connects India's mainland, Myanmar and Bangladesh and about no rail tracks. The state is housed in various folds and faults over Indo-Burmese tectonic zone (Indo Eurasian plate tectonics), and housed adjacent to 95^0 Ridges. The booming craggy state is combatting with its road network progress due to frequent low magnitude tremors, landslides, floods, and heavy rainfalls.

The data of earthquakes, landslides, rainfall, and road progress were collected, and analyzed. The connectivity growth is reported tough and challenging within forests, broken relief, frequent ghats roads, and deep gorges, in topography that hinders the progress in pavement growth. Present study focuses on the ameliorative measures of hill road construction in Mizoram by adhering to the IRC: 52-2019, changing modus operandi of national contract bids, amateurish engineering design, procurement policies, bidder's expertise and commitment for execution.

The non-availability menial labours and technocrats have stemmed many legal issues & disputes between the government and the contractors. Faulty planning, engineering design, executant's approach, procurement policies and the contractor's skill, contract administration and construction

**Corresponding author: E-mail: 2sibamishra@gmail.com;*

management, road safety challenges, contract documentation, and inability of deployed bidders needs to be improved in Mizoram. To cater the needs of up-gradation/ new constructions, the hurdles warrant cutting edge impulses through EIA, EMP, DPR, amateurish design, and updating procurement policies that should supersede the orthodox practices.

Keywords: Contract polices; engineering design; earthquakes; Mizoram; landslides; hill roads.

ABBREVIATIONS

NDMA: National Disaster Management Authority; EQ: Earth quake; NER: North East Region; GoM: Government of Mizoram; GoI: Government of India;IRC: Indian Road Congress; GIS: Geographical Information System; RS: Remote Sensing; IMR: India and Myanmar; DGPS: Digital Global Positioning System GPR: Ground penetrating radar, A. Pr.: Arunachal Pradesh; km.: Kilometer; ha.: Hectare; INR: Indian national rupees; IMR: India and Myanmar; NH: National Highway; SH: State Highway; MDR: Major District Roads; ODR: Other District Roads; VR: Village Roads; VDF: Very dense forest; MDF: Medium dense forest; BUSG: Built-up Steel Girder; RCC: Reinforced Cement Concrete; PWD: Public Works Department: GSB Gr: granular sub-base grade; CTB: Cement treated base; Mixed sealed surfacing; NCB: National competitive bid; MoRTH: Ministry of Road Transport and Housing; NHIDCL: National Highways and Infrastructure Development Corporation Ltd; DPR: Detailed Project Report; EIA: Environmental Impact Assessment; EMP: Environmental Management plan; GSI: Geological survey of India; NLRMP: National Landslide Risk Mitigation Project;

1. INTRODUCTION

Assessing the risk and its mitigation of the impacts of earth quake (EQ), and landslide hazards are herculean task. The risk of slope failure, subsidence and measures for risk reduction is challenging for the highway engineers, geo-technocrats and decision makers in the hill road connectivity programs. Landslides and earth quake in India are considered as one among earth's lethal disasters. The human activities like deforestation, land use alternations, structural constructions, and road projects in hilly areas are triggering the landslides. Landslides are often activated by anthropogenic activities, quarry formation and power projecst. The Mizoram state is a state among the other 8 states of North Eastern Region (NER), i.e. Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura (Fig. 1), (Table 1).

Table 1. The status of NER states area, population, roads etc. (NECS, GOI, India [1])

Name of state	Area(2011 census)	Population (2011 census)	Total Forest Area	Roads length	Railway y Length	Cropped area	2011/Forest Covering hilly dists.
	Km2	000's	Km2(2013-14)	Km(2013-14)	Km(2013-14)	000's Ha (2013-14)	No of dist ricts /(%)
Arunachal Pr.	83743	1382.6	51540	21555	01	276	13 /80.5%/
Asom (Assam)	78438	31169.3	26832	241789	2459	4100	03 / 68.8%
Manipur	22327	2721.8	17418	19133	01	233	09/ 76.5%
Meghalaya	22429	2964.0	9496	11984	00	336	07 / 77.0%
Mizoram	21081	1091.0	16717	9810	02	487	08/ 90.7%
Nagaland	16579	1980.6	9222	34146	13	123	08/ 80.3%
Sikkim	7096	607.7	5541	4630	00	144	04/47.3%
Tripura	10486	3671.0	6294	33772	151	309	04/ 76%
Total NER	262179	45588.	143360	376819	2627	3226	86 / 55%
ALL India	3287263	1210193	692027	4690342	64600	198969	741 /21%
NER % (India)	7.976	3.767	20.716	8.034	4.067	1.621	

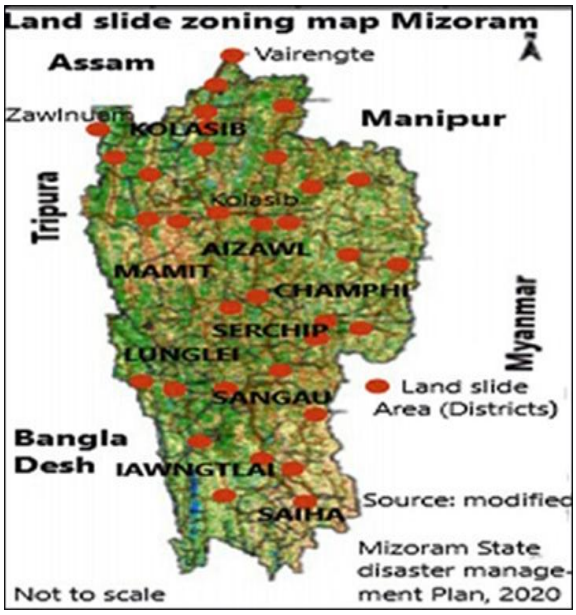

Fig. 1. The index map of the Mizoram state with major landslides

The NER has forest cover is 20.72% out of the 7.98% of total geographical area of India. The hilly states in NER like Nagaland, Mizoram, and Arunachal have forest cover >80%. The geographical area of the Mizoram state is 21081Km^2, and forest cover of 19117Km^2 (90.68%) as per 2011 census. All the eight states of NER are growing since inception from 1986 after attaining state status. Keeping pace with demographic growth they are flourishing like urbanism, road networks, health, and education sectors [1]

2. REVIEW OF LITERATURE

Earthquakes and landslides are frequent in the NER states, and India is ranked 6th most hotspot expanse on earth due to shifts along the thrusts, faults and stability failure that has evolved through tectonics, geological, fluvial, and anthropogenic processes Tiwari et al. [2], The recurrent seismicity of high and low magnitude in the NER of India and Myanmar (IMR) range are caused by collision of Indo-Eurasian tectonics accompanied by subduction due to inter-continental collisions [3-11]. The NER of India suffers from frequent landslides especially during torrential monsoon rains being triggered by frequent seismic activities, torrential rain and lithology of the area. The landslide zonation map of various districts in Mizoram by GIS studies have been reported for Chhiahtlang in Serchhip district [12], Aizawl [13], Mamit Township [14], Kolasib area [15]. The zonation map has helped planners for future development of land slide disrupted areas for the communication network. Land slide has been turned in to disaster in recent past in Mizoram convoyed by subsidence, landslides and rock slide triggered by monsoon heavy rainfall [16,14,17].

Apart from NH, SH, MDR, ODR, Village roads, the hill roads can have smaller dimensions like one lane motor roads (one lane), Bridle paths (Pedestrians path for plying of one jeep of width 2.45m to 3.65m & slope 1:8 to 1:10), and village paths (with 1m to 1.2m of slope ≥45^0, ruling gradient of 1:7.5 and limiting gradient 1:5), https://civilnoteppt.com/12-types-of-classification-of-hill-roads/.

Many research studies have been done on the earthquake and landslide prone areas in Mizoram. Fewer studies are available about the ground realities and huddles created during growth of the old road network constructed during pre-independence. The lacunae in fast developing road setups need to be investigated and specify the ameliorating measures in the present frame work of fast Mizoram connectivity program.

2.1 Mizoram State

Mizoram lies in the southern fringe of NER (Lat.: 21°58’ N to 24°35' N and Long.: 92°15’ E to

93°29' E), extending North - South: 277 Km, East - West: 121 Km.. The peripheral states are Tripura in north-west, Assam in north and Manipur in the north-east. The bordering countries are Myanmar in east and Bangladesh in northwest of border length 404km, and 308km respectively. The state has population density 52persons/km^2, and literacy rate 88.5, and high effective literacy rate 91.33% [18].

2.1.1 Climate and forests of Mizoram

The Mizoram Remote Sensing Application Centre (MIRSAC) has reported >70% of Mizoram state has ghats and hills areas with ≤35% gradient. The year 2011 and 2012 had total rainfall in the state were more than 4000mm. The state receives heavy to very heavy rainfall of annual average ≥2555.23 mm during south west monsoon (MJJAS months) of the year (Fig. 2).

The Forest Report of the Mizoram state, 2019, mentioned the state possess forest shield of 18748km^2 (88.93%) of state area (138 km^2 very dense forest (VDF), 5,858 km^2 moderately dense forests (MDF)), and the VDF area are gradually declining due to human accomplishments. Particularly the bamboo coverage area has declined from 9245km^2(2011) to 3476km^2(2019), https://www.nezine.com/info/.../state-of--forest-report,-2019:-arunachal-pradesh-and-mizoram

2.1.2 The road network Mizoram

The roads in Mizoram are under the various stages of rehabilitation, renovation, and new constructions since last decade. The landscape of the Mizoram is ordinarily rolling hills with large valleys with settlements and townships located on hills sides. The state is growing fast as transit and trading zone to the bordering countries Bangladesh, Myanmar, and with SE Asian countries. Future improved connectivity through proper road links shall upsurge the thinly settled state, Kumar et al. [19], Rodrigue et al. [20], Hmingsangzuala et al. [21].

As per PWD data 2018-2019, all the types of existing and the ongoing project of roads were totally 8911km comprising of 7224km (MSDMA 2020) were surfaced and 2101km unsurfaced. To maintain continuity about 140 nos. of various bridges like RCC (43nos), PSC (Pre-Stressed) 15nos, Built-up Steel Girder (BUSG) 30 nos., Suspension Bridge/Cable stayed 4nos., Bailey Bridge (Temporary) 45 nos., and Timber Bridge (Temporary) 6nos. are existing and needs to be renovated n Mizoram PWD, GoM AR [22] and MSDMA,GoM-2020 [23] **(Table 3).**

The NER states houses, 0.18 MKm2 hilly areas including Darjeeling and Sikkim. These areas are prone to landslide and included in Zone-IV and V (MM scale VIII to IX). https://www. gsi. govin/webcenter/portal/OCBIS/pageGeoInfo/pageLANDSLIDEHAZRD, Bhattacharya, [24].

3. WHY MORE LANDSLIDES IN NER, INDIA

The Mizoram states lies adjacent to 95^0 ridge and well covered by vegetation over hills with steep slopes which covers the subduction zone of Indian and Burmese tectonic zone and near Arakan trench. The area was highly prone to

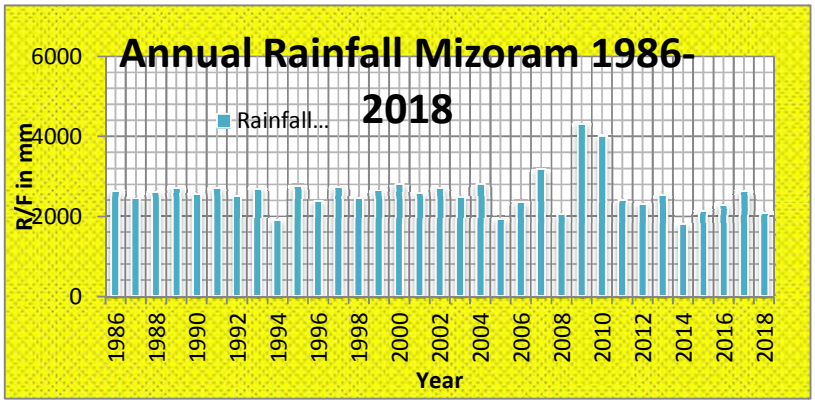

Fig. 2. The time series plot of rainfall of the Mizoram state from 1986-2018
(Data: https://mistic.mizoram.gov.in/storage/source/SCCC/publications/Rainfall)

Table 2. Status of existing NH in the Mizoram state India in 2019

New NH No.	Starts from	Terminate at	Intervening townships	Old NH No.	Length in Mizoram (km)
2	NH-15 (Dibrugarh)	Tuipang (Mizoram)	Sibsagar and Amguri (Assam), Mokok-chung, Wokha and Kohima (Nagaland), Imphal, Churachandpur (Manipur), Seling, Serchhip, Lawngtla, Tuipang).	150 & 54	483.5
302	NH-2 (Theriat)	B-desh border	Lunglei-Lungseni- Tuiehong; (Kawr-puichhuah)	54A	109
502	NH-2	Saiha	Venus Saddle,and Saiha in Mizoram	54B	27
502 (A)	N.H-2	Myanmar border	Lawngtlai and Kaladan Road in Mizoram	502 (A)	100
6	NH-27 (Jorabat) (Assam)	Zokhawthar (Miz oram)	Shillong, Dhaleshwar, Kanpui, Aizawal, Selling, Lumtui, Khawthlir, Tuisen, Neihdawn, Champai ends Zokhathar	54	266
102 (B)	NH-2 Churachandpur	NH-6 (Keifang)	Singhat, Sinzawl, Tuivai Road in Nagopa, Hliappui, Saichal, Keifang	102(B)	140
108	NH-8; (Manu; Tripura)	NH-6 (Aizawl)	Mamit, Lengpui, Sairang; Aizawl	44A	165
306	NH-6 (Kanpui)	NH -37 (Silchar)	Kanpui (Mizoram) ; Silchar (Assam)	54	72
306 (A)	NH-306 (Vairengte)	NH-2 (New Vertek)	Saiphai, Zonmun	306 (A)	60

(Source: MoRTH; GOI)

Source : https://morth.nic.in/sites/default/files/Details-of-National-Highways-as-on-31.03_1.pdf

Table 3. Status of road network, in Mizoram, India; (Mizoram State PWD, report 2018-19)

#	Type of Highways/ Roads	Length	Conc./Bitumen	WBM/ Earthen
	Existing and under annual R/M	(km)	(km)	(km)
1	N H (National Highway)	1,410.50	1,322.50	88.00
2	S H (State Highway)	170.20	170.20	Nil
3	Major District Roads (MDR)	502.30	440.30	62.00
4	Other District Roads (ODR)	764.73	580.33	184.40
5	Village Roads (VR)	1,695.12	563.23	1,131.89
6	City roads (major & arteries)	343.43	319.11	24.32
7	Towns & Village (RWT&V)	842.85	672.10	170.75
	Sub Total I	6,765.00	4,940.25	1,824.75
	Roads under construction			
I	Roads under BRO	894.48	618.29	276.19
II	Roads under CPWD	175.60	175.60	0.00
III	Roads under other Deptts	1076.67	1076.67	0.00
	Sub-total II	2146.75	1870.56	276.19
	Total Roads connectivity	8911.75	6810.81	2100.94

Source: https://pwd.mizoram.gov.in/uploads/attachments/8a08427f21c4299397d597ce3786dcce/ annual-report-2018-2019.pdf

tectonic activities during Holocene epoch. The EQ's of lower magnitude (M-5) are recurrent in Mizoram and that causes land slide by loosening overburden. Triggered by SW monsoon heavy rainfall, landslides aggravate. The burgeoning population, modernization, urban growth are aggravating deforestation and changing land cover. The runoff reaching underneath the sand stone layer is favoring land slide in stringent hill slopes.

3.1 The History of Earthquakes in Mizoram

The NER of India and the adjoining areas of Myanmar and BD were the 3rd largest hotspot areas in the globe for seismic activity. In post Holocene period devastative EQ's were reported in NER states during 1546, 1596, 1601, 1642, 1663, 1696, 1749, 1772, 1832, 1848 and 1851. Some EQ's having less historical evidence like 1931 (Assam), 1932 (Nagaland), 1957, 4th Jan. 2016 (Imphal), 3rd Jan 2017 (2021 (Assam) having magnitude <7.0, and had less impact Devi, [25]. In 2020, small or large 16numbers of EQ's occurred in NER (M<5). The most recent EQ's are in Sikkim on 18th Sept. 2011, Assam EQ (M = 6.4), occurred on 3.1.2021 and in Manipur (M=3.6R) on 20.06.2021at Ukhrul, Fig. 3(a) and 3(b).

In Mizoram the intensity of EQ's are less than 5. Some major seismic activities NER states from 1869 to till date was collected, and causes were identified in NER states and damages caused by them (M-scale >6) are given in Table 4.

3.1.1 Seismic activities in Tripura-Mizoram fold belt

The Bengal Basin is a low seismic zone due to intra plate movement and the folded belt. Tripura is moderately EQ active due to plate boundary activity. The EQ's at Srimangal in 1918 (M=7.6) was the Sylhet fault within the Bengal Basin affected Mizoram. The Cachar EQ of Tripura fold in 1984 (M=5.6) might have occurred due to Sylhet fault movement. The tectonic domains of Mizoram are initiated by Dauki fault (E-W trending), Sylhet fault (N-E trending), N-S Jamuna fault, MNW Tista fault, Mat and Tuipui faults, and the lineaments at NE-SW Hail – Hakula, , N-W Padma, [2].

3.2 Hills Ranges and rivers in Mizoram

The Mizoram state is housed in hills of Mesozoic era. Mizo Hills are part of the Arakan Mountains, sequence of parallel ridges and river valleys, with N-S trending. The rocks are sandstone, shales and limestone of Cenozoic era formed 2.6 - 65 MYBP. The road network runs through the 23 numbers of hills of Mizoram. Major hills ranges are Phawngpui (Blue Mountain) of (2157m high), Lengteng (2141m), Surtlang (1967m), Lurhtlang (1935m), and Lunglei (1105.3m), and others, https://mizoram.nic.in/about/hill.html. *The rivers running* are the Barak (Tuiruang), Tlawng

(Dhaleswari, 185.15km,), The Tuirial (Sonai), the Tuivai, the Chhimtuipui (Kolodyne, 138.46km), has tributaries the Mat, the Tuichang and the Tiau (159.39km),the Tuipui, and the (R.Karnaphuli, 128.08km), [30].

3.3 Past Landslides in Mizoram

The state has lithological strata embraces top soils as overburden of about 9-10m underlain by poor or very poor silty shale or shale sandstone, or sandstone or lime stone, (Panigrahi et al., 2011 [31], Verma R., 2012, [32] 2013 [33], 2014 [34]) (Table -5), (Fig. 3(a). The correlation between rainfall and landslides are given in Fig. 3(b).

3.4 Land Slide Vulnerable Areas along Hill Roads

The serpentine hill roads of NER states are susceptible to landslides. The reasons are the active tectonics, fragile geology, heavy monsoon rainfall, critical slopes, high relief, and more infrastructural development after Mizoram got state status from 1987. The connective roads are running through landscape of common topography ≥25% slope along the hill bypass through bends and curves. The ridges are in subduction zone, and under inter-plate stress field of IAP, (Indo-Australian plate) (Fig. 5(a) & Fig. 5(b)).

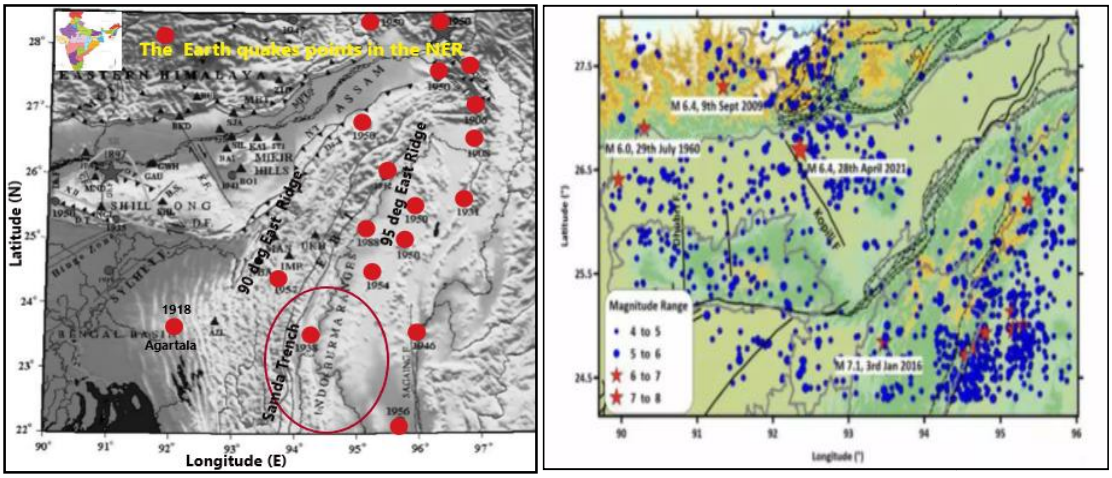

Fig. 3(a). Large EQ's of Mw >7 in Past along 90^0 - 95^0 E ridge along NER states Fig. 3(b): The EQ incidences in NER states of Mw>4 (Source modified: Srivastav 2011 & Viswa Mohan 2021.

Fig. 4(a). NH disrupted when land slide near Mizoram (Hilmen quarry),
Source: Rakhist et al 2017 [40].

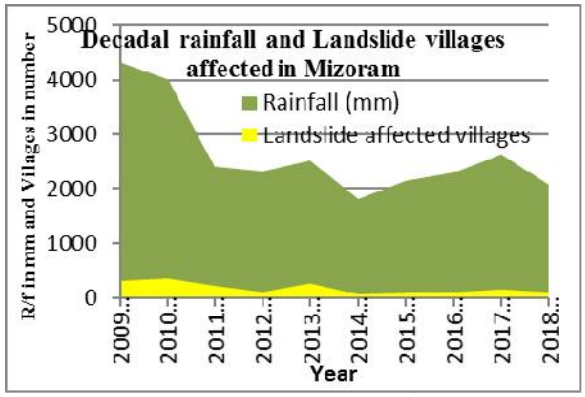

Fig. 4(b). The decadal rainfall and the villages affected by land slide 2009-10 to 2018-19;
Source: Rainfall induced hazards analysis of Mizoram(MISTIC -2016 [37])

Table 4. Some hazardous Earthquakes (Magnitude M≥ 7.0 in NER, India in past

Name of EQ	Occurrence Date	Lat (N)/Long (E); epicenter	M-scale	Resulted from Fault, thrusts and slips
Cachar (Assam)	10th Jan. 1869	25.50N/ 93.00E	7.38	GSI 1st EQ studied by (Oldham), Kopili Fault)
Shillong Plateau (Meghalaya)	12th June 1897 17:11 IST	25.50N / 91.00E	8.7	Seiches in Myanmar; Landslides; Dauki Fault
Sibasagar	31st., August 1906	Upper Assam (NA)	7.0	Neotectonic activity; Fluvial geotectonics Brahmaputra R.
South Meghalaya Srimangal (BD)	8th July 1918	24.25N / 91.70E,	7.1	Shillong-Mikir massif; Sylhet fault,
South Meghalaya (Mymensingh)	9th Sept. 1923	24.94N / 90.32E	7.1	Dauki Fault zone; within the Shillong Plateau
Dhubri;Meghalaya	3rd July 1930	25.80N/ 90.20E,	7.09	Amid Dhubri & Brahmaputra fault (west margin)
Kopili Valley EQ	23rd Oct. 1943,	26.00N / 93.00E,	7.2	Kopili Fault, near Jorahat
Arunachal Pr. EQ	29th July 1947,	28.50N / 94.00E	7.3	Main central thrust MCT
Assam Tibet EQ	15th Aug. 1950,	28.50N / 96.50E	8.6	Dextral strike-slip, Indo China border, Po-Chu fault
Pataki range (Arunachal Pr.)	15th Aug 1950	NA	7.0	after Tibet tremor on same day, property damaged
Manipur-Burma border	21st Mar 1954	NA	7.4	property damaged
Darjeeling	1959	NA	7.5	Property damaged
Indo-Myanmar border	6th Aug 1988	NA	7.8	Landslides, fissures, ejection of sand, mud and water
Sikkim Earthquake	18th Sept 2011	27.72°N,88.06°E, depth 20.7 km	8.0	Movement of Fault, ∼11 mm at Phodong co-seismic shift

Source: Das P. K. 2008 [26], Dashgupta S., 2011 [27], Srivastave P.P. 2011 [28], Das S. 2021 [29].

Table 5. Few landslides causing disruption of traffic in Mizoram (1986 – till date)

District /state	Date	Landslide location	Cause L.S.	Impact
South Hlimen	11th July 1986	Quarry site	Quarrying	Landslide/rock slide
South Hlimen; Rock slide	9th & 10th Aug, 1992	South Hlimen quarry site	Quarrying	planer & toppling failure
Aizawl.& Chandmari	2004-05 &2005	Armed veng/ & Chandmari west	Heavy rain	Houses collapsed
Tripura border	Sept, 2007	Mamit District	Heavy rain	NH-44A closed for 13 days
Jaintia hills, Meghalaya	12th May 2010	NH-44; Tongseng-onapur	Heavy rain	Traffic upset from Tripura-Mizoram &South Assam
Aizawl	11thMay 2011	Laipuitlang	Land slide	killed 17/injured 9
Aizawl	8th Aug 2012	Aizawl-Tuirial road	Rain/Mock flow	3-dead:Taxi down crag
Ramhlun sports Complex	July 2013	Ramhlun Vengthar	Rain & Mining	Houses damaged
Aizawal, Mizoram	27th Aug 2015	Many districts (Mizoram)	Heavy rain	Massive landslides & roads disruption
Lawngtlai & Saiha	15th & 16th May 1995	Lawngtlai & Saiha town	Cloudburst &Landslide	360 mm of rain, 34 death house-467
Champhai dist. of Mizoram	2004	Ngopa Village	Landslide/Subsi-dence	45 buildings and 55 families affected
Bawngkawn; Aizawl	24th-27th Sept, 2015	Ngaizel, Kulikawn Chaltlang North; Ramhlui Vengthar Cemetery; Chanmari	Heavy R/F; Pulal-chhuanthanga,Vengthar cemetery; Hunthar; collapse retaining wall at Chanmari	Graves damaged, NH- 54 disrupted; Dam Chhawnzinga Tuik-huah choked; Blocked Thuampui-Bawngkawn
Hunthar Veng	21st Aug., 2016	Hunthar locality	Heavy rainfall 13th August, 2016 (Sinking zone)	Hunthar Veng huamchhunga NH-306 (old NH54)
SE part of Aizawal	17th Sept., 2017	Sikulpuikawn-Bethlehem Veng road	Rain (sewage & later bottom shale mud erosion	top most shale bed to move down the dip slope (48°-50°)
Hnahthial	11th June 2018	Hnahthial, Kanan veng	Quarring	Regular from 2004 & NH 306 part damaged
BSUP Complex, Durtlang	02nd July 2019	Durtlang Leitan in Aizawl	Heavy rain	Rock blocked and debris
Hilmen Smartland	22nd June, 2020(Monday)	Hilmen Smartlandroad	past 2 nos EQ, SSW Champhai /ENE Aizawl	Quarry land slide one dead, (ANI report)

Source: Tiwari et al. 1996 [35], Kumar, et al, 1997 [36], MISTIC- 2016 [37], MSDMP- 2020 [38]; Jangpangi 2020 [39], http:// www. mizenvis. nic.in/Database/Disaster_1222 -2021

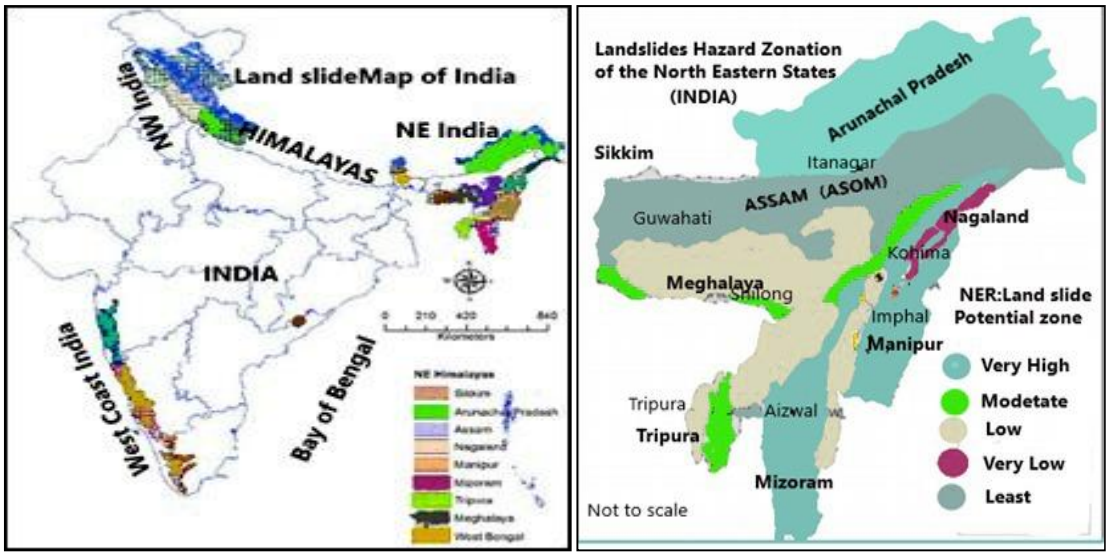

Fig. 5(a). The Land slide map, India & Fig. 5(b). Landslide zone map of NER (Data NDMA):

The EQs can be linked with thrusts, faults, and shear zone over state's lithosphere. Mizoram lies over many thrusts like Main Central Thrust (MCT); Easter boundary Thurst (EBT), Main Boundary Thrust (MBT); Main Frontal Thrust (MFT) and faults within the hills at Dauki, Dapsi, Naga, Dudhnoi, Oldham, Chedrang, Kopali, Disang, and along the Brahmaputra. (Shrivastav et al. 2011 [28], Dasgupta et al. [27], Verma R. 2014 [34],https://mistic. mizoram.gov. in/storage/source/SCCC/publications/Rainfall.

3.5 Why Landslides Transpire

Landslides happen when a mass of rock, debris or earth moves down a slope which can be translational or rotational (spreads or flows). The initiating causes are lithology, limnology and stratification of the area along with past histories of earth quake, continuous rain or anthropogenic interventions to slopes. The slope, weathering, erosion, vegetative cover, under cuttings also plays vital role. The cloud bursts, floods, mining, dam failure, and roads or building constructions, that changes the land cover can also invites landslides.

3.5.1 Landslide affected Roads networks

It is high time to segregate the landslide zoning at national level, regional or state level, locally, and site specific to have better plan for connectivity across the hills supplemented by various maps of different scales such as landslide inventory map, susceptibility map, hazard, and risk maps; along with reports framed from time to time for better design of road/railway and infrastructural development. One such immediate highly identified vulnerable road is from Aizawl airport to the township, Fig. 4(b) and Table 6).

3.5.2 Hill roads vulnerable areas to land slide

Most of the hill roads in Mizoram are plying through landscape topography ≥25% slope. These hill highways (NH or SH) having a longitudinal cross slope ≥25%, are found at the bypasses through bends and curves. Aizawl is centrally located and the focused entry/exit point. It is the heart of the roadways network of the state. All the connecting NH, SH and arterial roads in Aizawl are susceptible to landslides and in hazard zone [40].

3.5.3 Future EQ in NER states

Dr. Roger Bilham, eminent of Colorado University, has delivered in a workshop "EQ Risk Mitigation Strategy Asom" that the Himalayan region have ruptured in ensuing EQ's (Mw<7.8). He has foreseen the NE Himalayan region shall face a major catastrophe by rupturing with high magnitude EQ's (Mw>8.2). Similarly, Dr. Gupta, NGRI, Hyderabad has predicted the EQ in Indo-Myanmar border to continue 21^0 N to 25.5^0 N lat., and 93^0 E to 96^0 E in NER, India of magnitude (Mw> ± 8) considering the periods of earthquake swarm and quiescence, https://nidm.gov.in/PDF/pubs/EQ%20North%20E

ast.pdf,, Srivastab et al. [28], Agarwal [41], have reported that there is prediction of frequent EQ's of small magnitude in the Mizoram as high magnitude EQ's generally follows numerous small ones. The numbers of earth quake activities shall alter the stratigraphy of the area.

3.5.4 Roads affected by landslide in India

National Disaster Management Agency (NDMA) has prescribed guiding principle on landslides prone areas are provision of open weep holes, construct water harvesting structures, more afforestation by native faunal species, immediate repair of rain cuts, displays by sign boards and indicate signals to sharp, reverse and pin bends for easy drive and safety of the hilly road users,.https:// vikaspedia.in/social-welfare/disaster-management-1/natural-disasters/landslides

At present sensor-based landslide pre-warning arrangements have been introduced in the vulnerable hill roads immediately. The guidelines of National Landslide Risk Mitigation Project (NLRMP) of the Planning Commission, India and the National Disaster Management Authority (NDMA) are followed. Application of GIS/RS is introduced by GoM for preparation of data base and is being implemented adhering to the landslide zonation map. The use of the alteration of the land use and land cover of the terrains and the hill slopes and its stability should be investigated and necessary action to be taken to reduce the future losses.

3.5.5 Survey and investigation of hill roads in Mizoram

Mizoram state has to plan for road infrastructure to cater needs of 212241 numbers of vehicles (MSDMA report 2020 [42]) The survey of roads requires the horizontal and vertical (line and grade) layout for each strategic areas. Modern methodology in road planning applied in India is the approval of the environmental impact assessment (EIA), Environment management plan (EMP), and administrative approval (AA) from the competent authority apriori. The National Highway authority of India should focus on proper highway alignment through a hilly terrain emphasizing the stability of slopes, the potential landslide prone areas before heading to construction phase. These potential areas shall involve where huge amount of cutting, filling, quarrying and debris disposal. They are indispensable as they affect the natural stable slope.

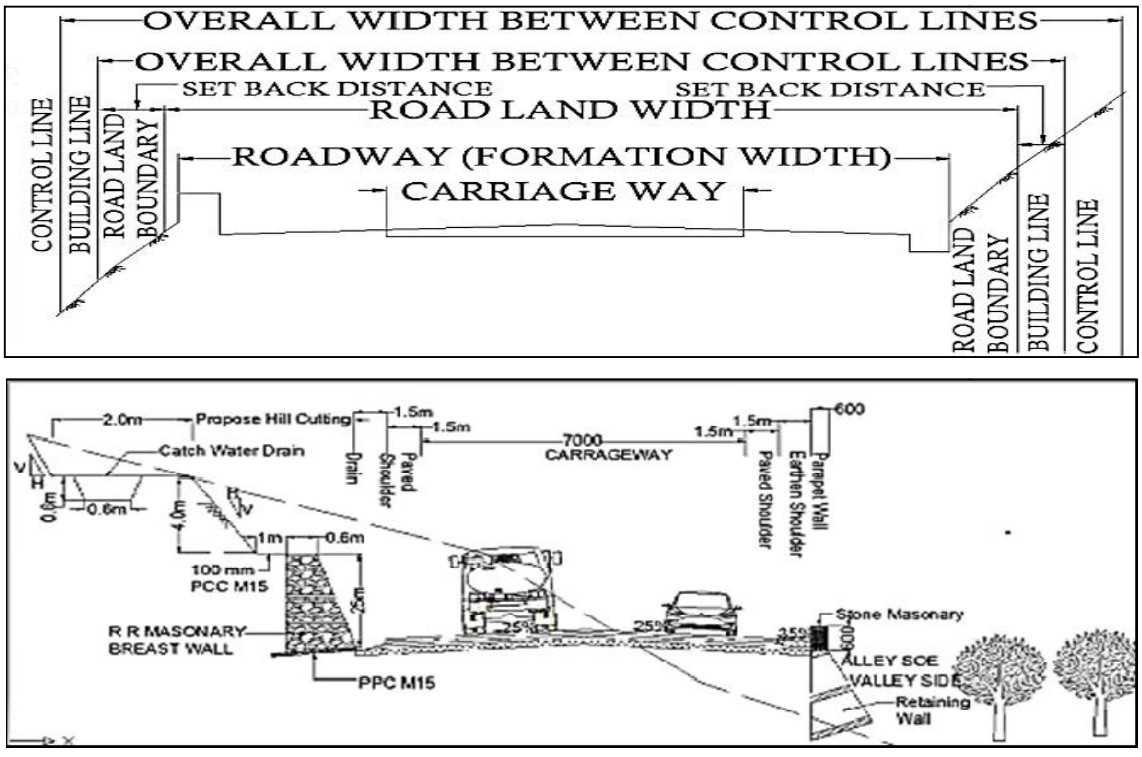

Fig. 6. (a) & (b). Planning for a road section one lane and two lane roads with all control lines

Table 6. Landslide zone susceptible as hazard zone in Mizoram

Land Slide hazard class	Cause of the Hazard	slope characteristic	Area in Mizoram	% area of the state
Very High hazard zone	Heavy Rainfall, near faults, bald, faults, Joints, many bedding, EQ tectonic zone,	Very steep slope, avoid Road network; unstable	1822.48km^2	8.65%
High hazard zone	Debris over burden, weathered rock, Land slide prior, quarries, faulty & fractures, unstable	Very steep slope≥45^0(drainage erosion or sparse forest)	4263.79km^2	20.22%
Moderate hazard zone (areal extent)	Heavy rainfall, seismic activity, relative compact rocks, moderate trees,	steep slope, township on top soil removal ideal	≈ 8903.04km^2	42.42%
Low Hazard Zone	low slope failure, dense forest, Road network can be done	≤30% slope, sparse soft sediments or unconsolidated	≈ 5011.57km^2	23.77%
Very low Hazard Zone	Plain forests, no towns ,land slide free, best for road network	≤30% slope, soft &consolidated sediments	≈ 968.72km^2	4.60%
Water body areas	rivers, drains, lacustrine areas like swamps etc.	costly for road net- work (avoid)	≈ 111.97 km^2	0.53%

(Source: MSDMA-2020[38])

The NH/SH networks construction and there management in elevated hill regions are much different than plains. They are frequently pretentious to continuous heavy rain, floods, frequent land/ rock slides, subsidence. From IRC: 19 -1977 to IRC:52- 2019, leniency has been given to delimit the design criteria's for hill road design if not affected by excess cost involvement. The alignment survey and geometric design of hill roads, alignment of tunnels (2001), IRC: SP: 48-1998, IRC: 52 -2001, and updated in IRC: 52 -2019 [43] are in practice. The engineering design has been revised as per the revisions of according to Hill Roads and Tunnels Committee (H-10) -2018. While planning or designing; the code of practices are to be followed considering the disturbed geology, terrain degradation, sedimentation, soil erosion/ landslides, change in land cover/ deforestation, drainage outline, ecosystem, and aesthetics of the area.

3.6 Aerial Reconnaissance

During planning, stress should be imposed on aerial reconnaissance surveys like LIDAR, drone surveying, GIS/RS applications in field of survey rather than traditional surveying methods. If required the help of aerial photography, Digital Global Positioning System (DGPS)/ Ground penetrating radar (GPR), Theodolites, binoculars, total stations can be used for survey of roads undertaken for upgrading/ new constructions. The strategic planning should be done as per the high scaled contoured 1:1000 or 1:2000 for smart grid transport network indicating marsh land, road or river crossing, mines, religious arena, HT lines, towns, cities, and all the vulnerable points. The survey of existing road network (NH/SH) whose renovation or upgradation are to be taken up with ground trotting, change in alignment avoiding the most vulnerable zones like hair pin bends, S-curves, steep slopes, old dilapidated bridges and slope protection measures indicating possible alternate routes, structures and control points (Fig. 6 (a) & (b)).

3.7 The People and the Terrain

The Mizoram is the major road connectivity between Myanmar, Bangladesh, and mainland of India. The road network runs through the hill roads are often short straights, alternating hills and valleys with sharp bends, narrow, zigzag, snaky and with steep slopes at numerous locations. These factors cause the road engineering in the state a herculean task.

Mizoram is one among the heavy rain fed area (Av rainfall 2550mm) essentially need adequate drainage on the hill slope side. The sedimentary rock formations in the sand-loamy or clay-loamy overburden provide less bonding and the sedimentary rocks of Neogene or Tipam. Formations (lime stones/ sand stones are less monolithic are susceptible for landslide.

3.7.1 Maintaining Superior geometric standards

The road network of per and post independent period was as per old engineering geometric practices during World War II. Those were lacking adequate/perfect engineering techniques, improper planning, lack of geo-technological investigations, and study of geohydrology. Present expansion/ new alignment should adhere to proper ruling gradient within optimum length, minimizing/ avoiding hairpin bends, steep gradient, and unnecessary topography rises/falls, unsound sub-soil, land slide/erosion of hillslope *etc.*. The locations with improper geotechnical

Table 7. Base-width/ shoulder range (both sides) 2-Lane (≥7m) in open and built up areas in hills

Type	Range of base width (open area)	Range of base width (built area)	Site condition (Hill side /or valley side)	Total width of carriage;	Minimum Roadways width
NH/SH	18m – 24m	18m - 20m	Open (1.5m + 2.5m)	4.0	11.0m
			Built up (1.75+1.75m)	3.5	10.5m
MDR	15m - 18m	12m – 15m	Open (1.5m + 2.5m)	4.0	11.0m
			Built up (1.75+1.75m)	3.5	10.5m
ODR	12m -15m	09m – 12m	Open (1.5m + 2.5m)	4.0	11.0m
			Built up (1.75+1.75m)	3.5	10.5m
Village roads	09m	09m	Open (1.5m + 2.5m)	4.0	11.0m
			Built up (1.75+1.75m)	3.5	10.5m

Table 8. Engineering design relations as per IRC:52-2019 like super elevation, transition curves (IRS:52-2019 [43])

Characteristics	Equation	Symbols	why necessary/ special features
Super elevation (IRC:52-2019; p-27-29)	$e = {V^2}/{225R}$ e (/m width of road way)=superelvation	; V is vehicle speed of in KMPH ; R (m)= curvature radius	To counter centrifugal force effects; kept limited to 10% in hills; super elevation > camber; It is given in the abutments with uniform deck slab thickness.
Minimum curve radii (IRC:52-2019; p-29)	$\frac{v^2}{gR} = e + f$ Where; e (m) = Superelevation; R (m)=radius of curve	v = speed in m/sec; g = accel^n due to gravity m/sec^2; & f = Coeff. of friction with road & vehicle tyre (take 0.15)	Min^m radii (m) in Hor. Curves in hills is NH /SH 50-80; MDR: 30-50; ODR: 20:30 and VR: 14-20m. In steep gradient NH/SH in hilly terrain is 30-50; MDR: 14-30; ODR: and VR: 15-23m
Transition curves (IRC:52-2019; p-30-31)	Min^m of two value $L_s = \frac{0.0215V^3}{CR}$ & $L_s = {V^2}/{R}$	Ls (m) = length of transition; V = speed in km/h R(m) = radius of curvature C = 80 / (75+V) (max^m 0.8 and min^m of 0.5)	Smooth pass from straight into to circular reach. Min^m L_s for different V (50, 40, 30, 25kmph) and curve radii (100, 125, 150, 170 m) is 15 or as per p-31 of IRC:52-2019-
Widening (IRC: 52-2019; p-31)	Extra width (2-Lane) provided for widening of horizontal curves for R= 0-40m is 1.5m; R=41-60m is 1.2m and R=61-100 is 0.9m and R>100 is 0,6m		
Set-back distance	m= R-(R-n) Cos θ where $\theta = \frac{S}{2(R-n)}$; m (mtr) = the min^m set-back distance to sight block;	R(m) = radius at center line of the road n(m) = distance C/C road & inside lane; S (m) = sight distance	For one-lane n=0; R (m) up to 30m, sight distance 30m, and vel30km/hr the setback distance is 3.7m. For other values the IRC:52 – 2019 page 31 can be referred

strictures of landscape origin or subsoil strata must be moderated through structural solutions. The rainfall and climate change also alters the hydrology/ geohydrology of the area. They must be attended through proper drainage network. The superior geometric standard, and design parameters such CBR-value, K-value and SBC-value must be considered during planning and design. The design criterion as per IRC: 52-2019, the terrain classification are plains (0-7^0), rolling (7^0 – 14^0), mountainous (14^0 – 31^0), and steep (>31^0) to the horizontal must be taken in to accounts. As a sample the road base width assigned for 2-lane roads in hills area as per IRC:52– 2019 [43] are: (Table 7 and Table 8) are:

3.7.2 Additional needs

Additional right of way for proper sight distance; extra land for future development, rain cuts, high fills, unstable and landslide locations; parapet (o.6m width extra) on valley side if retaining wall/ other structures are provided; Embankment if >6 m high, then Kerbs with channel are erected; 1.3m divider/median is provided extra in case of one way roads; Camber should be provided in 1 in 50 to 1 in 40 in thin flexible roads and 1 in 60 to 1 in 50 in high type thick bituminous road.

3.7.3 Conditions

Super elevation is not needed when the radii of camber in meter is 2% for design speeds30, 35, 40, 45kmph are 200, 270, 350 and 550 respectively (IRC-52 2019 p-28). In case blind curves (where sight distance < stopping distance) benching or vision curves are provided.

3.7.4 Renovations in old existing network

The sections which has become critically deteriorated and continuously causing disruption in traffic flow needs to be attended by opting old slope protection measures by Skirted Strip Footing. [44], Bayan et al. [45], Ghosh et al. [46].

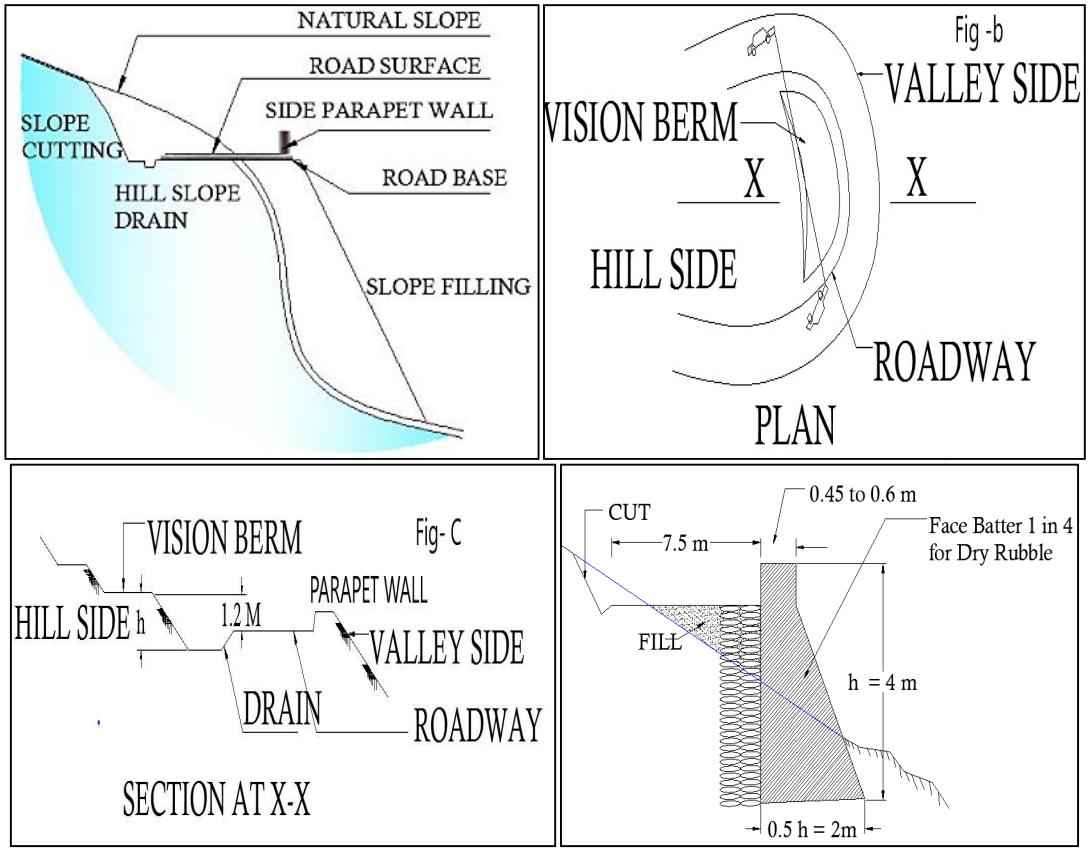

Fig. 7(a) & Fig. 7 (b). Roads along the hilly areas in high altitude and sharp bends (IRC: 52-2019) Fig. 7(c) : Construction of retaining walls at vulnerable points of the hill slope (IRC:52-2019)

The vertical skirt is constructed adjacent to the footing base that confines the underlain soil by generating skirt side soil which prevents the sliding of the mass retained. The old existing roads of World War II period have been damaged or not adequate to accommodate the present traffic volume. The renovation, alternate, upgradation or new roads are required to house the increased traffic. All types of roads in Mizoram demand renovation or alternate routes along with new connectivity (Fig. 7 (a), Fig. 7(b) and Fig. 7(c)).

4. DISCUSSION

The Mizo's are modernized, educationally updated, urban centric. So there is horizontal space constraint in towns. There is non-availability of appropriate modern building development code for construction, transport, electricity, water supply, health care for a state over hills, and their management, Mazumdar K 2011 [47]. Central Mizoram is the foci of all emanating rivers and the most hazardous zone for land slide. There is recurrent road communication distraction as an impact of land slide and torrential rainfall. The land use and land cover map helped in zoning of the land slide prone areas and it is observed that the urban development along with infrastructural communication network.

4.1 Procurement Strategies

Mizo's are well educated, the 2nd largest educated state of India with less population density 52 persons/km^2 as per MSDMA-2020 [38]. The state is booming astoundingly in education, health, economy and with Per Capita Income at Constant Price 111786 INR/annum. The marginal labours are only 71675 which is 0.065% of the population 2011 census, (Economic survey Mizoram, 2019-20 [48]). Paucity of work force, middle management and contractors are main hindrances in the road sector in Mizoram. During construction key construction plants and equipment to work in steep gradient with high execution risks, and limited work space are common issues. Additional constraints for procurement of men, materials and machineries from other states with problem of land acquisition, quarry sources, and quality stones, long lead time for quarrying, work encumbrances, interferences and land ownership are the main issues in roads under progress. The construction period overruns due to high cost involvement, contractor's unpreparedness and less machineries, faulty reconssiance survey, detailed site investigation, and old engineering design adds to the delay in the sector.

4.2 Engineering Strategies for Old Roads

During renovation, repair and maintenance of roads, the technocrats should vigilant about the foundation, adequate drainage, elasticity of pavement, pot holes, rain cuts, shoulder repair, filling, clearances, hill side drains, choked culverts, landslide debris depositions. The drains, side parapet walls and retaining walls need to be repaired regularly and promptly. Stability to the cut slopes must be provided with proper structure or cutting during construction phase. The excessive blasting should be avoided in the area which may loosen the rock and cause threat to the ecosystem. Vision berms and obligatory points are to be provided with signals as per site requirement. Crossing of hill ridges or hills, tunnels can be an alternate choice if possible, http://www.arunachalpwd.org/pdf/Section (Section 14 - Special requirement for Hill road). The IS codes and IRC specifications such as provisions of IRC: SP: 48-1998, IRC:52-2001, IRC:52 – 2019 are to be strictly followed. Under unavoidable situation the hair pin bends are to be provided with circular round with adequate transitions. Non-availability of separate lanes should be adjusted by separate climbing lanes with road marking and signals for the entire reach. Provisions of possible minimum haul/ diversion roads are to be constructed and maintained prioritizing existing Haul roads. During renovation or improvement of the existing roads, there is necessity of relocation, renovation of old structures that disrupts the traffic flow. Minimum 6.0m wide diversion roads with minimum subbase (GSB gr-1= 100mm thick), cement treated Base course (CTB = 150mm thick), mixed sealed surface as wearing coat (MSS = 20mm thick) with proper shouldering are to be provided for continuance of the connectivity in a 2-Lane diversion with regular water sprinkling to avoid dust [49].

4.3 Engineering Strategies for New Constructions

During new constructions, the first option is preservation of top soil after excavation for reuse to avoid extra cost. They can be used for enriching nearby embankment slopes for turfing and erosion protective measures or filling up the supporting borrow areas. They are to be earmarked prior. Ecologically sensitive areas

Fig. 8. Some pipeline works under progress of NH in Mizoram (Courtesy: Er. J. Nayak, BBSR)

need to be cleared. Before alignment, the extent of excavated areas is to be demarcated and indicated through signboards for knowledge of personal areas, or grazing zone. The pre-identified magazine area need to be in a distant safe area (Fig. 8).

Material, specifically the aggregates should be sourced carried by spillage proof containers from approved quarries as per contract clauses. Occupational safety of the workers of the area must be maintained during quarrying process and regular inspection shall be carried out [50].

4.4 Inferences

The low population density, increased literacy, agrarian community, mobility, modernization and surged possession of motorized vehicles have demanded to augment its road network in a small but resourceful state like Mizoram. The road construction in Mizoram is complex. Previously it was mostly vulnerable to early deterioration by natural phenomenon like heavy rainfall, flash floods, landslides, *etc.* but now anthropogenic interventions to nature has increased the complexity.

Present engineers and the workmen can contribute faster to withstand against the natural adversities and provide an optimized solution by using modern technologies, guidelines, research and model studies, field survey etc. The judged solution to the problems is to preserve old roads by renovation/upgradation to horizontal and vertical structures Nayak & Mishra et al. [51].

Mizoram Road Projects have brewed numerous incongruities between the executant, designer and the executor. This has connoted great snag between contract administration and work accomplishments during the construction phase. The land acquisition (LA), non-receipt of approved drawings, have increased time over run resulting delaying the payment modalities by non-sanctioning of extension of time (EOT), deviations and project cost overruns.

The planning and designing stage urges for accurate traffic study (volume and quality), efficient engineering design. The environmental impact assessment (EIA), environment management plan (EMP), faulty engineering design, and alignment, trade-off between funding sources, time, cost, quality and contracting norms should be organized before execution phase.

Realistic surveys, planning, design estimates, and preparation of bids are essential. Failing to adhere shall hinder the work progress at site and put heavy losses to the contractor and the government incorporating delay and cost overrun of the project.

The study also revealed that in hills region the road condition has deteriorated and degrading continuously after the completion of the roads due to small magnitude tremors, frequent landslides and anthropogenic interventions.

The structural failure to existing road network in Mizoram state are due to nonexistence of drainage structure and slope protective measures like retaining wall, parapet wall, breast wall, culverts and drains *etc.*. The construction phase demands adequate supply of water, key consumables, experienced work force, and construction materials. Measures must be taken for adequate drainage, hill slope protection, retrofitting land slide zones and preparedness for unprecedented rains, tremors and landslides.

The breakdown structure of the physical progress, financial progress and budgetary

allocation must be synchronized. There is lag between the demand through bills and payment. There is also delay in release of funds by the departments due to non-submission of utilization certificate by the departments.

There is acute shortage of local workforce in the level of marginal labours and even contractors from the state in road sector. That allures the inland farms and agencies to pour into the state and engage themselves as a part to their development but ignorant about the federal law, climate, soil, drainages, geology, hydrogeology of the state. In housing sectors they can adopt but the steep valleys are the strategic locations where they fail. Lacks of skilled engineers, improper survey, poor design and low quality men, materials and machinery, have spoiled the project's progress. COVID-19 has stopped the work progress through shut downs, migrations and curfews.

The base line survey should not be neglect the nature and biodiversity. The various factors to be considered are the physiography, soil and its erosion, landslide, slope and its stability, land use, land cover, soil productivity, flora, fauna, avifauna, surface and underground water, mines, human use values, culture, and updated population of 1.309lakhs in 2020.

After completion of the road project, there is necessity for road safety by providing cautionary and informatory Signals, marking pavement, glow markers on roadside trees, protective structures for pedestrians and traffic, and intermittent gates for the safety of flow of traffic.

5. CONCLUSION

The Mizoram state is climatologically vulnerable to meteorologically extremes, challenging unsecured landscapes, sloped topography, prone to low magnitude EQ's, mountains, and river gorges. Though. Mizoram is affected by frequent low magnitude EQ's and affected by landslides. These regions are sporadically settled where basic livelihood and infrastructural amenities are not accessible as in plain terrain. Conclusively, to ameliorate the communication teething troubles, robust, unwavering, established, and feasible roads is of utmost demand of the Mizo's. Those hilly terrains are flourishing under complete infrastructural growth of the Mizo's but their mobility are under chains due less progress in land connectivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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