Snow and Road Pavements in Western Himalayas

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The Paper deals with snow effects on road pavements in the Western Himalayas with special reference to the upper reaches where high altitudes, rugged topography & difficult working environment, & heavy depositions of snow combine to produce characteristically difficult road conditions. The Paper discusses the salient aspects of road work, including the over-all effects of snow depositions on pavement performance. It is brought out that granular crusts topped with thin bituminous surfacings, which are otherwise satisfactory, undergo considerable damage every year due to the effects of snow clearance operations. The aspects of direct mechanical impingement and water action are discussed. The Authors hold the view that due to conditions of deep ground water table, frost action is only of low intensity & there is no significant problem of frost heave. The work already done and further work indicated for the solution of the said recurrent damage to pavement are also discussed.

In Western Himalayas, roads may be said to provide the most important means of linking the population pockets in far-flung and high altitude areas with the rest of the country. Over the years, need is being felt for higher and higher level of road access, both in quality and quantity. Provision and operation of road net-work involves a number of special features, relating to high altitudes, rugged terrains, and associated climatic and other factors. Snow action, in its various forms, exerts a dominant influence on the various pavement aspects - design, construction, maintenance, trafficability, etc.

By now, considerable amount of road work has been handled in this region, thus providing fairly good insight into the various special regional road problems. Described in this paper are the prevailing road conditions, the evolution of various practices, and the outstanding problems.

General Road Conditions

Terrain

Road work in Western Himalayas involves very high altitudes and extremely steep cross slopes. At some of the passes, roads have to negotiate altitudes of the order of five thousand meters and there are roads with average altitude above three thousand meters. The horizontal and vertical alignments change almost continuously and there is a heavier component of formation work & of retaining and drainage structures. Change of elevation in relation to the limiting gradients necessitates the use of zigs, involving hair-pin bends at times (Photos 1,2,3). The road lengths are therefore considerably more in relation to the distance in plan.

Photo 1. A view of the typical topography encountered in the region.

Photo 2. Distant view of a road section with bends and zigs.

Photo 3. Road winding around a steep hill slope.

The terrains involved include solid rock, weathered rock and schists, conglomerates, soil-boulder mixtures, and soils of low to medium plasticity. On account of various factors, a road is generally developed in stages from foot-path to mule-track, to jeepable track, etc.

Climatic Factors

Quite severe temperature conditions may be said to prevail in theses parts. Summer-time day temperature may well exceed 30 degrees C, whereas the night time temperature in winter may dip to minus 20 degrees C, or even to minus 40 degrees C. Within a span of twenty-four hours, temperature variations in the range of 30 degrees C are not uncommon. Rainfall is generally not heavy, being scanty at higher altitudes where most of the precipitation is in the form of snow-fall.

Conditions with regard to snow-fall vary widely in the region. Snow-fall is light in the valleys at lower altitudes. At the same time, there are locations with snow depositions of as much as 30 meters. With the prevailing terrain and climatic conditions, snow slides and avalanches are fairly common. Shown in Figure 1 is the position with regard to snow-fall and avalanches for a section(negotiating a pass) of an arterial road connecting Ladakh with the northern plains through Jammu & Kashmir. For its conditions of terrain, snow-fall & avalanches, & transportation needs, this road section may be said to present a characteristically difficult case. At the present, the road remains blocked due to snow from November to May-June. The cost of protective structures (Photo 4) & effort involved in the arduous task of continuous snow clearance come in the way of keeping the road section open during winter. Durin April-June, snow clearance is carried out within a span of about 2 months for the 78 km length of road on the two sides of the pass, involving snow volume of the order of 1.5 million cubic meters.

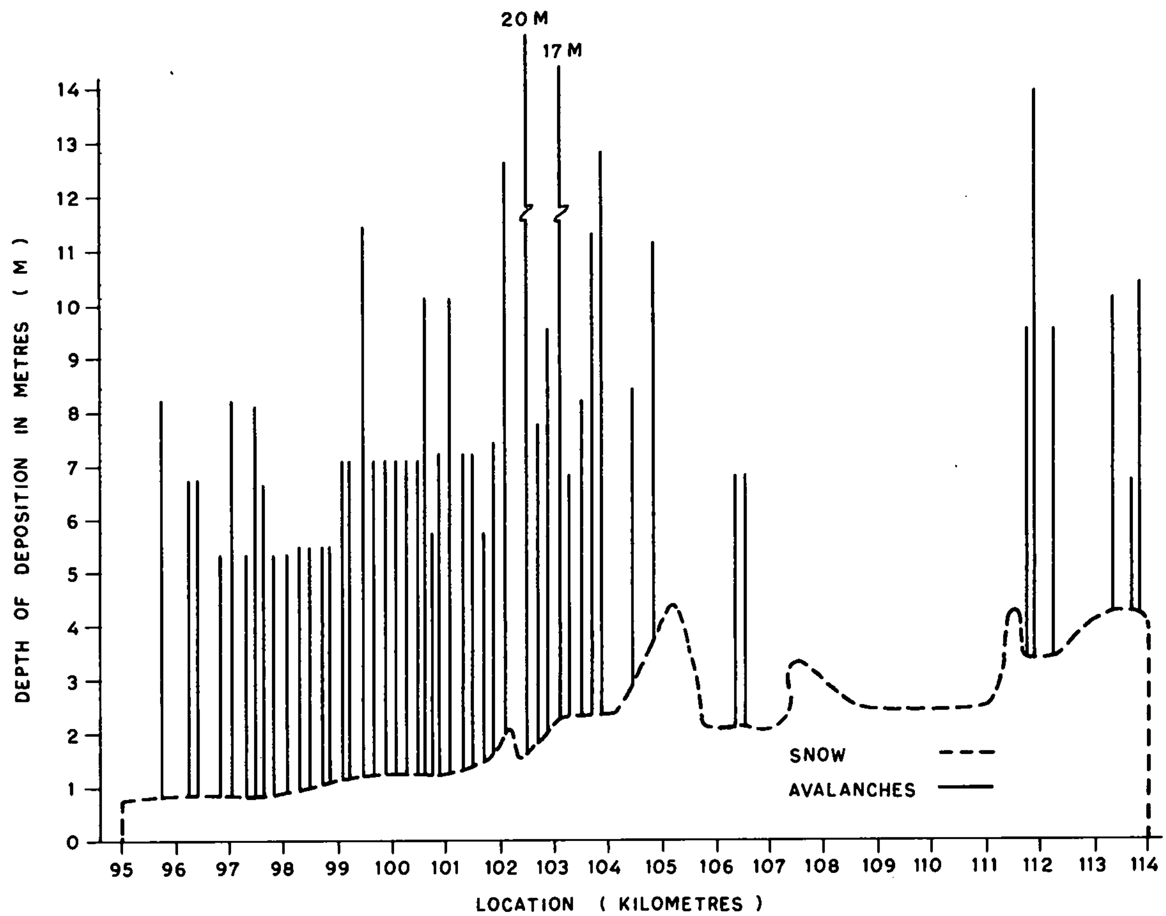
Photo 4. A typical snow-shed - one of the few protective structures provided for safe & unhindered movement of traffic.

Work Organisation

It goes without saying that the high altitudes with raefied air, rugged terrain, low temperatures, & unfavourable general physical environment combine to lower considerably the efficiency of both the man & the machine. A different pattern of organisation has been found to be necessary for road works in difficult areas.

Varying mixes of man & machine are being adopted for different operations, & for the same operation in different situations. Vis-a-vis practices in developed countries, manual inputs are higher in all operations (Photos 5 & 6).

Figure 1. Extent of depositions due to snow-fall & avalanches on a section of road at a high pass.



Pavement Aspects : Snow & Associated Factors

Carriageway Conditions

The non-urban roads have single carriageways of one to two lane width. The shoulders are generally unpaved although they are covered with pavement here and there for providing extra widening of the carriageway on curves & for providing lay-byes for crossing & storage of vehicles. On the downhill side is provided a discontinuous parapet of 0.6 meter width & of about the same height. On the hill side is provided a shallow longitudinal drain. The retaining walls and breast walls are done in stone masonry in cement mortar, dry stone work, or stone rubble crated in wire-netting. Of late, crib walling is also being used. Bridging & cross drainage works are largely with conventional methods. Initial temporary bridges are being progressively replaced with permanent structures.

Pavements are of flexible type, by and large. Barring limited stretches here and there with sub-bases of stabilised soil or soil-gravel, the crust is composed of granular sub-base and base courses, generally topped with thin bituminous surfacings(surface dressings or thin open-graded premix surfacings). In the recent years, pavement strengthening measures have included the use of 5-8 cm thick bituminous surface courses. Excepting a few important links carrying medium to heavy traffic, the traffic is generally light. For the fair to good subgrade conditions,therefore, the crusts required are not heavy.

Snow Deposition & Its Clearance

In the region under reference, extent of snow deposition varies rather widely. In southern parts at lower altitudes, snow-fall may range from none in a particular year to about a meter. There are no significant problems of avalanches or snow slides in these parts. Larger accumulations result only here & there due to deposition of drift snow. Further north at higher altitudes, the position is quite different. Snow falls quite frequently, amounting to a few meters during the season. In a case like that shown in Figure 1, however, the depositions may be as much as 30 meters, largely due to drift action, slides, avalanches, etc.

The approach to and methods for snow clearance tend to vary quite notably. In southern parts at lower altitudes,snow-falls are occasional. Light depositions from a snow-fall, if not melted by the warmer weather the next day, is taken care of largely with manual methods. In the case of a single fall, or two or more falls in quick succession, one lane is first cleared on the carriage-way and additional clearance follows, depending upon the weather, the need and resources available. In towns also in these parts, the above approach is followed largely. For bye-passes and other trunk facilities, however, equipment is used for snow clearance as per availability.

On the other end of the scale is the case of the arterial road section, presented in Figure 1, where the depositions are much heavier, falls more frequent, & working conditions extremely difficult. In these northern parts at higher altitudes, the snow fall season is essentially from November to April although some snow may be received in October and May also in the upper reaches. Upto November and after April, the weather is generally balmy enough to cause melting of snow. Total intensity of snowfall and its distribution during the snow season tend to vary from year to year. The month of heaviest snowfall is invariably between January and March. It has been observed that the intensity of snowfall can be 3 cm per hour and more. Short-term (for a few hours) intensity of upto 4 cm per hour has been recorded for this reach. Heavier snow-falls at higher intensities lead to triggering of avalanches (Photo 7). At the start of the snow season, there are simple flakes which change to compound flakes later.

As stated earlier, the road section is

Photos 5&6 : Some typical mixes of man and machine.

Photo 5.

Photo 6.

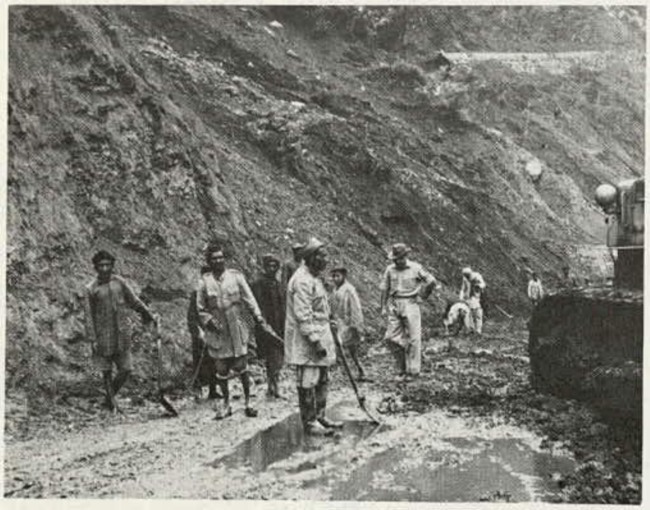


Photo 7. A view with glacier in the back-ground.

Photo 8. Start of the snow clearance operations towards the end of snow -fall season.

normally closed to traffic from about November to about May. The work of snow clearance is started in April, by when temperatures have risen enough & snow starts melting. The clearance work is usually completed by early June.

Over the methodology for this work has been undergoing change. Earlier the back-bone of the operations was the dozer. Then were brought in snow-ploughs & low-capacity snow machines. Currently, quite high capacity & heavy duty machines are being employed for these operations. After some preliminary work by the tracked dozers these snow machines are brought in to clear the snow, in two or more runs, from central one lane width (Photos 8, 9 & 10) for the initial corridor. Sufficiently high route-markers provide the much needed navigational guidance for these operations. This corridor permits movement of controlled traffic. Further clearance work is carried out by the various items of snow removing equipment. The dozer continues to be a very expedient means of shoving small snow banks down the hill-slope. Gaining experience over the years, a fairly effective regimen has been evolved to complete the task in good time and in safety.

For conditions in between, the methodology consists in the deployment of smaller machines and less over-all mechanisation.

Pavement Aspects

The effects of snow deposition and associated factors on pavements vary from location to location, depending upon the deposition, its clearance and other related conditions. The pavement composition normally used(as described earlier) has been a fairly satisfactory low-cost solution for cases where snow depositions are light. For a case like the one of Figure 1, however, conventional pavement undergoes considerable surface & structural damage as a result of clearance operations, requiring be made up every year. Therefore, discussed in the following paras are the various pavement aspects for this case.

The direct mechanical effect occurs in two ways: from the sliding down debris and the clearance operations. Avalanches and glaciers bring down debris which interalia causes boulders of various sizes to impinge upon the pavement with considerable impact. As a result , spot damage is caused to the pavement. More significant and wide-spread damage is brought about by the operation of clearance machinery. Even though most of these machines are intended to operate so that 15 to 20 cm thick cushioning layer of snow is left, there is impingement due to error in judgement accentuated by the changing vertical profile. The operation of tracked tracked vehicles causes still higher damage. Mounting of rubber shoes on the tracks has since been introduced but significant damage is still caused during fast directional changes which are sometimes unavoidable and which at other times result from deficient skill in work or pressure for time. An associated aspect is that of breaking and removal of thin layers of ice formed on the pavement surface with the freezing of water present, from melting snow or otherwise. The relatively gross methods used for this situation also add to the pavement damage.

Photo 9. Snow clearance in progress.

Photo 10. Initial corridor cut through a deep snow deposition.

It is believed that deeper damage , though at a slower rate, is however caused to the pavement by water action involved in clearance operations. By April, when snow clearance is started, conditions of snow melting start operating. When the initial corridor is being cut, there is a tendency for the water from molten snow to flow in this corridor. Wherever there is already some surface damage or where there are conditions of water stagnation, this water finds ready access into the relatively pervious pavement. At locations of slides/ avalanches and even otherwise, debris and mud are generally present. These also tend to go into the pavement. Drainage channels are being cut across the snow banks to minimise the flow of water in the corridor ; but continuous supply of water, blocking of regular drainage systems and continually changing profiles, etc. lead to profuse entry of water to saturate the pavement. It goes without saying that there is heavy traffic soon after the road is opened, having remained closed for over half an year. Softening of the subgrade, profuse water present in the pavement structure & on the surface, and heavy pneumatic tyred traffic combine to weaken the pavement structure in various ways, leading to deformation and surface deterioration.

Even though frost formation is a fairly common occurrence, it is felt that conditions do not exist generally for frost action to become significant. Freezing index/frost penetration is quite considerable at a number of locations, some of the soils are also fairly frost-susceptible, temperature change rate can also be conducive to formation and growth of ice lenses but it is believed that frost action is not able to assume any significant proportion because of the generally prevailing condition of deep ground water table. From enquiries & various field observations, no locations could so far be established that had suffered from any notable heave due to frost action.

Possible Solutions for the Recurrent Pavement Damage

In the back-ground of pavement conditions described above for locations of heavy snow depositions, a number of alternative solutions come in for consideration :

1. Having pavement with low-cost surfaces which can be readily restored at the end of the snow clearance operations each year.
2. Having special pavement that can withstand the clearance operations though may not necessarily provide high enough serviceability level.
3. Having pavement with high type surface courses which while providing high serviceability levels can also last longer against clearance operations.

As stated earlier, the locational factors are such as favour development of road in stages with regard to alignment & geometrics, formation width, & pavement. With regard to alternative 1, pavement for the case of Figure 1 remained unsurfaced for some time. Top course of water-bound-macadam was reprepared each year. Provision of thin open-graded surfacing does not alter the situation very much except that better-riding surface is available. The main handicap of this solution is the high frequency of surface renewal required. The serviceability level obtained is also not high.

Earlier work had shown that stone-set pavement is able to withstand better the operation of tracked vehicles. Some limited field trials have already been made with this type of pavement and it would appear that further work is necessary from the point of its construction and riding quality. Provision of cement concrete pavement entails the problems of higher initial cost, higher construction time in the face of little scope for diversion of traffic, and of course higher losses in reaches susceptible to slides or warranting improvement of alignment/geometrics. Use of higher types of bituminous surface courses offers a good compromise from the point of cost,durability, and serviceability level. Their use, on progressive basis, is to be considered in stable and finalised reaches. Low-void bituminous mixes would need to be studied from the point of performance under conditions of very low temperatures and large temperature variations.

Concluding Remarks

In Western Himalayas, there are, in the upper reaches, the conditions of very rugged terrains and high altitudes with the associated low temperatures and heavy depositions of snow. In some of the reaches, there are very heavy accumulations of snow on the roadways due to the combined effects of direct deposition, drift action, slides, and avalanches. For various reasons, a number of road sections are allowed to remain closed to traffic, due to blocking with snow, for a good part of the year. Towards the end of the snow season, snow clearance work is started. These clearance operations cause adverse conditions of mechanical impingement, water action, etc. As a result of these effects, flexible pavements made up of granular crust topped with a thin bituminous surfacing undergo extensive damage recurrently. Such a pavement is found to be fairly adequate otherwise. Some work has already been done with modified/different types of pavement. Simultaneously, measures have been evolved for minimising adverse conditions from clearance operations. Further work is indicated for trials with stone-set pavement, stabler low-void bituminous surface courses for the pertinent environmental factors, & other possibilities.

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