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# THE SNOW DRIFT PROBLEM AND ITS EFFECTS ON ROAD SAFETY IN TURKEY

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ABSTRACT

Snowdrift problem along Turkish highways is regarded as part of the winter maintenance. It is treated as snow fighting and the usual procedure is snow removal and ice control. The snow removal and ice control are closely dependent on the winter meteorological conditions, the amount of traffic and geometric and physical design of highways. A very large expenditure is needed for the maintenance of the roads in winter.
Snow accumulation on the roads is mostly due to snowstorms. It distorts the traffic.

Snow removal and ice control process consists of following three stages:

Design and construction of highways to avoid snow drifts, hauled by wind

Build up snow fences to avoid drifts on highways

Remove the accumulated snow and ice, and decrease the slipperiness of the road and increase the friction between the tire and the pavement to a safer value ; 0.45

In this paper, snowdrift problem will be dealt with the available statistical data. As case study the snow drift problem faced along the Istanbul- Edirne Motorway, Tekirdağ- İpsala, Uzunköprü- Meriç State roads, and the type of the solutions will be presented. Up to present, four different types of snow fences; Canadian, Russian, Swedish and recently precast concrete fences were used in Turkey. The market conditions and the availability of the material dictated the choice. Canadian and Russian types have vertical slats, whereas Swedish type has horizontal members. The most recent type used is made of precast concrete members with a much smaller porosity and high catch efficiency, but the linear meter unit price is twice more than others. When wood and plastic fences are used , they are burned down during the field-clearing fires set up by local villagers at the end of harvest season. Recently precast concrete fence units were preferred wherever the road conditions permit.

**Key Words:** Turkey, winter maintenance on roads, snow drift, snow fence

## 1. INTRODUCTION

The General Directorate of Highways; (TCK), having an organization all over Turkey, is responsible from the planning, design and construction of motorways, state roads and provincial roads in accordance with the standards set up to meet the increasing transport needs and to provide safety and comfort on highway transport.

General Directorate of Rural Services; (GDRS) provides transportation network facilities to rural areas, and constructs all roads to villages, and to related settlement units and municipalities which fall outside the state and provincial transport network system. In addition to such road construction, GDRS is also responsible for the ongoing maintenance, and upgrade their part of network. Moreover, bridges and other civil engineering structures are constructed for these roads as required, whilst necessary arrangements are made for traffic safety.

The responsibility for forest roads lies with the Ministry of Forestry. Municipalities construct and maintains urban roads.

## 2. PRESENT ROAD NETWORK OF TURKEY

The length of total highway network under the responsibility of TCK is approximately 63 156 Km, and consists of motorways, state highways and provincial highways. In Turkey, there are other types of roads like village roads, tourist roads, forest roads and urban roads, and they are under the responsibility of different organizations.

Tourist roads are constructed and maintained by the TCK with the finance by the Ministry of Tourism. Village roads are constructed and maintained by the GDRS and their total length is about 320 000 km. At present,. There are 75 753 small settlement they have units (32 962 villages and 42791 related sub-units) and all the villages in Turkey have road connection (GDRS 2000).

## 3. WINTER MAINTENANCE OF ROADS

The Maintenance Division of the TCK plans winter maintenance programs for motorways, state roads and provincial roads. In the same way, the winter maintenance of the rural road network is carried out by GDRS.
The amount of the roads taken into the winter maintenance program depends on the available funds, equipment, personnel and the physical conditions of the existing road network. Prevailing meteorological conditions dictate the realization and timing of this program. In snow removal, the priority is given to roads according to
Annual average daily traffic (AADT)
Industrial and military priority
Social and economical conditions of the environment and other available transportation means
From the point of view of winter maintenance, the existing roads are classified into three groups:

1. Open the year round under all winter conditions (controlled regularly)
2. Open under possible winter conditions (non-regularly controlled)

Roads closed in winter due to physical conditions of the road.

The available equipment and the trained personnel for winter maintenance are gathered at road maintenance houses, which are used as winter refuges. Both TCK and GDRS have their own winter refuges. The winter refuges are also grouped as the first, the second and the third class refuge according to their importance, and location in the network.

During 1975-1976 winter, 5000 personnel in 580 refuges with 1710 snow removal equipment like V type and straight blades mounted on trucks, rotary snow blowers, and graders were used by TCK for winter maintenance and 32 000 km state and 17500 km provincial roads (Arica, 1977).

Table 1. The road conditions of Turkey according to pavement type (http://www.kgm.gov.tr)

| ROAD CLASS | ASPHALT ROADS | STABILIZED ROADS | EARTH ROADS | PRIMITIVE ROADS | TOTAL |
|---|---|---|---|---|---|
| MOTORWAYS | 1 851 | | | | 1 851 |
| NATIONAL | 30 773 | 318 | 71 | 214 | 31 376 |
| PROVINCIAL | 25 846 | 2 297 | 1 042 | 744 | 29 929 |
| TOTAL | 58 470 | 2 615 | 1 113 | 958 | 63 156 |

But, during the winter of 1991-1992 an extraordinary situation was observed in the eastern Turkey. Due to very heavy snowfall, a series of avalanches closed provincial highways temporarily. The valley of Great Zap River, where Hakkari-Van highway runs parallel to the Great Zap river, experienced the most of the avalanches. Hakkari-Uzumcu section of the road had 83 avalanches in a distance of 23 Km. Van Regional Directorate of TCK spent about 6 million US $ to keep the 2230 km inter-city roads open to traffic, with a maintenance program covering 75 days. 620 workers equipped with 230 machines (grader, loader, 15 bulldozer and trucks equipped with straight blade and V-type blades) cleaned 37 million m3 snow, 1.7 million m3 avalanche ice and debris materials (Gurer, 1998).

In 2002, the winter maintenance program of TCK covered about 31 061-Km state and 27 259-Km provincial road. 20 33 Km (131 Km State, 1902 Km provincial) of roads could not be opened to traffic due to heavy snow (TCK, 2002). In winter 1999-2000, 3053 Km (361 Km State,2692 Km provincial) of roads could be opened to traffic due to same reason (TCK, 2000).

Compared to 247 000 m snow fence used in 1975-1976 winter (Arica, 1977), only 60 495 m new snow fences were used to prevent snowdrift on the highways, for the winter 1998-1999 (TCK, 1999). In 2001-2002 winter, 36 650 m new snow fence was erected to control the snow drift problem on Turkish highways maintained by TCK (TCK, 2002). Different types of snow fences like Canadian, Russian, and Swedish types had been used in Turkey (Fig.1 and Fig.2). Recently snow fences made of concrete panels were started to be used, but they are about two times more expensive than the wooden fences (Fig.3). The statistical information on the roads under the responsibility of Turkish Highway Department (TCK) since 1946 is given in Table 2 and the statistical data of the roads under winter maintenance program of TCK are given in Table 3 (TCK, 2002).

## 4. SNOW DRIFT CONSIDERATIONS AT PLANNING AND DESIGN STAGES OF HIGHWAYS

In planning and design considerations, the utmost attention is paid to build the roads on deep valleys and forests rather than open areas subjected to snow storms. Before planning and design of the roads, the prevailing wind directions of the project area should be determined either from the nearest available anemograph data or from climate atlas. It is also possible to study the drift direction from aerial photos, observing the bending of the trees and, drift around obstacles etc. The cut and fill sections of the roads may change the local wind vectors. The deep cut sections on the roads should be avoided in snow drift sections of the road. It is also necessary to have continuous wind measurements at critical drift areas along the roads.

In Thrace; the European part of Turkey, since the snowdrift is caused by the wind coming from direction of north, roads should be constructed on the slopes facing south. If the valley stretches in the north-south direction, the road should be constructed on the western slope. In this case the sun is more effective in the afternoon (Arica, 1977). The effect of snow as avalanche to the roads should also be taken into consideration. If the road has to pass through the snow drift area, the grade line of the road is raised above the adjacent ground level. The existing vegetation and the snowfall height define this amount of raise. Since the elevated roadway is a barrier to the free sweep of the wind, it causes eddies to form on both the windward and leeward

sides of the road. The transport capacity of the wind varies as the cube of velocity even a small decrease in velocity causes snow deposits in the drifts. Therefore the shape of the roadway influences the size, shape and location of the snowdrift. The interrelation among the length of eddy, the height of embankment and the wind velocity were determined for the case when highway is in cut. In deep cuts, snow can not be removed very far from the shoulders, thus causing high snow piles on the sides of the road (Finney, 1939). For snow drift there must be sufficient snow on the ground and the wind should be higher than about 4 m/s. The drift can also occur when the temperature is 0 C.

The physical life of the wooden snow fence was assumed as 25 years. The snow depth can be estimated by using the snow depth–elevation relation ( Naaim and Ancey,1992)

$S(z)=[S(zo)/2]*(1+z/zo)*(z/zo)$ …… (1)

where

S is depth of snow in cm

z is elevation in m

The height of the fence required can be determined from the monographs given by Tabler ( 1991).

## 5. CASE STUDY

The extraordinary the snow drift problem faced along the Istanbul- Edirne Motorway, Tekirdağ- İpsala, Uzunköprü- Meriç State roads ( Fig. 3) were examined by various field studies. In the state roads, the mainsnow drift problem was due to the wind that comes from the direction of the Black sea , the north. A detailed field survey and frequency analysis of snow depth in the region is needed to decide the height of the snow fence needed for different sections of the roads in the region. From the existing snow conditions it may be thought that a 3 mt. High and 220 mt. long of snow fences is to be built on the cut near Şarköy. The prevailing wind direction at Tepeüstü-Beğendik seperetion of Malkara-İpsala State Road is North. The height of drifted snow was 3 mt. and it was piled up by the wind when the site was visited. Also 6 mt. high snow piles was seen on the Istanbul- Edirne Motorway ; TEM highway at the place of the old pay-desks. It was observed that after the cut of long trees at the west junction of TEM higway, more severe snow-drift problem faced at Saray juction ( Bek and Gurer 2002).

Since the prevailing wind direction is fron the North and the road is going maily in East-West, the snow-fences is to be built paralel to the roads. The height of the fences will be determined according to the maximum snow depth and the water equivalent of the snow measured at the problem section of the road and the lenth of the snow fence will be fixed according to the lenth of the section road to be protected against snow drift (Gürer ve Bıçakçı, 1998).


Figure 3.The map of the roads of heavy snow drift problem was faced during December 2001.

Table 2. The statistical information on the roads under the responsibility of Turkish Highway

| Years | Asphalt Concrete | Surface covered | Stone covered | Stabilized | Compacted soil | Closed in winter | **Network Length** | Winter maintenance program | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Continous | Whenever possible | **Total** |
| 1946 | 294 | 539 | 104 | 19505 | 12813 | 10208 | **43463** | - | - | - |
| 1947 | 318 | 633 | 179 | 19513 | 12308 | 11026 | **43977** | - | - | - |
| 1948 | 331 | 707 | 196 | 20120 | 11341 | 11491 | **44186** | - | - | - |
| 1949 | 314 | 1091 | 177 | 20797 | 10598 | 11926 | **44903** | - | - | - |
| 1950 | 336 | 1111 | 177 | 22590 | 10311 | 12555 | **47080** | - | - | - |
| 1951 | 336 | 1251 | 177 | 23373 | 11623 | 12488 | **49248** | - | - | - |
| 1952 | 214 | 1575 | 129 | 24563 | 10577 | 12743 | **49801** | - | - | - |
| 1953 | 222 | 1811 | 146 | 25657 | 8121 | 14307 | **50264** | - | - | - |
| 1954 | 222 | 1781 | 149 | 26560 | 8068 | 14344 | **51124** | - | - | - |
| 1955 | 218 | 2497 | 189 | 28975 | 8956 | 14173 | **55008** | - | - | - |
| 1956 | 225 | 3343 | 173 | 31015 | 8856 | 13174 | **56786** | - | - | - |
| 1957 | 160 | 4380 | 183 | 32994 | 8497 | 11284 | **57498** | - | - | - |
| 1958 | 80 | 5157 | 171 | 34439 | 8858 | 9807 | **58512** | - | - | - |
| 1959 | 54 | 6101 | 153 | 34827 | 8820 | 10668 | **60623** | - | - | - |
| 1960 | 152 | 6741 | 156 | 34990 | 9168 | 10335 | **61542** | - | - | - |
| 1961 | 113 | 7795 | 145 | 34236 | 7834 | 10695 | **60818** | - | - | - |
| 1962 | 385 | 8591 | 119 | 33997 | 5722 | 10797 | **59611** | - | - | - |
| 1963 | 462 | 9646 | 198 | 33846 | 6832 | 7467 | **58451** | - | - | - |
| 1964 | 618 | 10229 | 236 | 33206 | 6290 | 7825 | **58404** | - | - | - |
| 1965 | 724 | 10163 | 156 | 28808 | 3139 | 8887 | **51877** | - | - | - |
| 1966 | 883 | 11231 | 228 | 30259 | 11579 | 5110 | **59290** | - | - | - |
| 1967 | 1002 | 12115 | 260 | 30334 | 11513 | 4457 | **59681** | - | - | - |
| 1968 | 1289 | 12712 | 207 | 31190 | 9319 | 4540 | **59257** | 32112 | 8928 | 41040 |
| 1969 | 1383 | 14093 | 204 | 30801 | 9422 | 3621 | **59524** | 32750 | 10274 | 43024 |
| 1970 | 1450 | 15884 | 207 | 29715 | 9331 | 3033 | **59620** | 33556 | 10398 | 43954 |
| 1971 | 1534 | 17481 | 211 | 28899 | 8517 | 2811 | **59453** | 33986 | 10294 | 44280 |
| 1972 | 1705 | 18516 | 204 | 28250 | 7965 | 2829 | **59469** | 34558 | 10006 | 44564 |
| 1973 | 1739 | 19318 | 206 | 27821 | 7784 | 2580 | **59448** | 34717 | 10095 | 44812 |
| 1974 | 1701 | 20458 | 191 | 27520 | 7201 | 2208 | **59279** | 35211 | 10090 | 45301 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 1764 | 21899 | 253 | 27260 | 6267 | 2056 | **59499** | 36507 | 11895 | 48402 |
| 1976 | 1892 | 23409 | 205 | 26033 | 5879 | 1651 | **59069** | 37508 | 12145 | 49653 |
| 1977 | 1912 | 24833 | 189 | 25009 | 6026 | 1646 | **59615** | 38060 | 11831 | 49891 |
| 1978 | 1996 | 26804 | 154 | 23067 | 5252 | 2134 | **59407** | 38334 | 11826 | 50160 |
| 1979 | 2336 | 29296 | 130 | 20913 | 5205 | 1838 | **59718** | 38724 | 12159 | 50883 |
| 1980 | 2707 | 31355 | 116 | 18745 | 4955 | 2181 | **60059** | 39088 | 12012 | 51100 |
| 1981 | 2822 | 32848 | 140 | 18508 | 4605 | 1838 | **60761** | 40077 | 11990 | 52067 |
| 1982 | 1900 | 34084 | 117 | 17258 | 4153 | 2200 | **59712** | 40313 | 12348 | 52661 |
| 1983 | 2937 | 35395 | 118 | 16169 | 4180 | 2155 | **60954** | 40756 | 11949 | 52705 |
| 1984 | 2936 | 36522 | 128 | 14715 | 3331 | 1665 | **59297** | 41056 | 11297 | 52353 |
| 1985 | 3176 | 37630 | 129 | 13750 | 2757 | 1670 | **59112** | 41113 | 11539 | 52652 |
| 1986 | 3368 | 38784 | 125 | 13019 | 2440 | 1566 | **59302** | 41529 | 12083 | 53612 |
| 1987 | 3851 | 39743 | 139 | 12020 | 1812 | 1574 | **59139** | 42098 | 12038 | 54136 |
| 1988 | 3972 | 41030 | 177 | 10767 | 1510 | 1459 | **58915** | 42446 | 12479 | 54925 |
| 1989 | 4161 | 41247 | 186 | 10293 | 1417 | 1547 | **58851** | 43112 | 11998 | 55110 |
| 1990 | 4128 | 42038 | 144 | 9558 | 1234 | 1450 | **58552** | 45115 | 10088 | 55203 |
| 1991 | 4261 | 43200 | 136 | 8803 | 1356 | 1372 | **59128** | 46438 | 9434 | 55872 |
| 1992 | 4414 | 43874 | 134 | 8050 | 1327 | 1422 | **59221** | 46804 | 9304 | 56108 |
| 1993 | 4546 | 44063 | 136 | 8116 | 1573 | 1408 | **59842** | 47472 | 9148 | 56620 |
| 1994 | 4605 | 44960 | 128 | 7352 | 1425 | 1300 | **59770** | 48139 | 8327 | 56466 |
| 1995 | 4757 | 45502 | 122 | 6894 | 1281 | 1276 | **59832** | 49067 | 7405 | 56472 |
| 1996 | 4835 | 45849 | 121 | 6552 | 1330 | 1312 | **59999** | 49376 | 7316 | 56692 |
| 1997 | 5080 | 46634 | 105 | 6007 | 1176 | 1223 | **60225** | 50081 | 7074 | 57155 |
| 1998 | 5136 | 47684 | 107 | 5574 | 1201 | 1139 | **60841** | 50307 | 7454 | 57761 |
| 1999 | 5659 | 48650 | 116 | 4141 | 1180 | 1139 | **60885** | 50744 | 7068 | 57812 |
| 2000 | 5752 | 49054 | 132 | 3761 | 1195 | 1029 | **60923** | 50489 | 7197 | 57686 |
| 2001 | 6057 | 49709 | 134 | 3026 | 1144 | 1020 | **61090** | 50683 | 7480 | 58163 |
| 2002 | 6452 | 50028 | 139 | 2615 | 1113 | 958 | **61305** | 50837 | 7315 | 58152 |

Table 3. Roads under winter maintenance program of TCK in Turkey ( Arica 1977, TCK 2002).

| YEARS | Roads That are open under all winter conditions (Regularly controlled roads) | | | Roads that can be open under possible winter conditions (Non-regularly controlled roads) | | | T O T A L | | |
|---|---|---|---|---|---|---|---|---|---|
| | State | Provincial | Total | State | Provincial | Total | State | Provincial | Total |
| 1969-1970 | 28 000 | 5 000 | 33 000 | 3 000 | 7 500 | 10 500 | 31 000 | 12 500 | 43 500 |
| 1970-1971 | 29 000 | 5 000 | 34 000 | 2 500 | 8 000 | 10 500 | 31 500 | 13 000 | 44 500 |
| 1971-1972 | 29 000 | 5 000 | 34 000 | 2 500 | 7 500 | 10 000 | 31 500 | 13 000 | 44 500 |
| 1972-1973 | 29 000 | 5 500 | 34 500 | 2 500 | 7 500 | 10 000 | 31 500 | 13 000 | 44 500 |
| 1973-1974 | 29 000 | 6 000 | 35 000 | 2 500 | 7 500 | 10 000 | 31 500 | 13 500 | 45 000 |
| 1974-1975 | 29 500 | 7 000 | 36 500 | 2 500 | 9 500 | 12 000 | 32 000 | 16 500 | 48 500 |
| 1975-1976 | 30 000 | 7 500 | 37 500 | 2 000 | 10 000 | 12 000 | 32 000 | 17 500 | 49 500 |
| | | | | | | | | | |
| 1988-1989 | 29 293 | 13 819 | 43 112 | 909 | 11 089 | 11 998 | 30 202 | 24 908 | 55 110 |
| 1989-1990 | 29 679 | 15 436 | 45 115 | 668 | 9 420 | 10 088 | 30 347 | 24 856 | 55 203 |
| 1990-1991 | 29 948 | 16 318 | 46 266 | 533 | 8 719 | 9 252 | 30 481 | 25 037 | 55 518 |
| 1991-1992 | 30 018 | 16 843 | 46 861 | 593 | 8 716 | 9 309 | 30 611 | 25 559 | 56 170 |
| 1992-1993 | 30 053 | 17 419 | 47 472 | 651 | 8 497 | 9 148 | 30 704 | 25 916 | 56 620 |
| 1993-1994 | 30 190 | 17 949 | 48 139 | 618 | 7 709 | 8 327 | 30 808 | 25 658 | 56 466 |
| 1994-1995 | 30 251 | 18 813 | 49 064 | 610 | 6 837 | 7 447 | 30 861 | 25 650 | 56 511 |
| 1995-1996 | 30 329 | 19 047 | 49 376 | 447 | 6 869 | 7 316 | 30 776 | 25 916 | 56 692 |
| 1996-1997 | 30 456 | 19 625 | 50 081 | 416 | 6 658 | 7 074 | 30 872 | 26 283 | 57 155 |
| 1997-1998 | 30 530 | 19 825 | 50 355 | 467 | 6 710 | 7 177 | 30 997 | 26 535 | 57 532 |
| 1998-1999 | 30 600 | 20 017 | 50 707 | 392 | 6 683 | 7 075 | 30 992 | 26 790 | 57 782 |
| 1999-2000 | 30 570 | 20 106 | 50 676 | 386 | 6 776 | 7 162 | 31 317 | 29574 | 60 891 |
| 2000-2001 | 30636 | 20047 | 50683 | 412 | 7068 | 7480 | 31048 | 27115 | 58163 |
| 2001-2002 | 30586 | 20251 | 50837 | 283 | 7032 | 7315 | 30586 | 27283 | 58152 |

## 6. DISCUSSION AND CONCLUSIONS

In Turkey, the existing practice is such that the roads are first built as economically as possible and opened for the service of the people. The snow drift problem can only be realized with the first winter, therefore the winter maintenance programs will always have snow drift and winter visibility problem component.

In practice, it is believed that in order to minimize the cost of snow removal thus the winter maintenance cost of the roads, especially motorways, it is necessary to have the minimum amount of snowdrift problem during the operation period of the road. For solving the snowdrift problem of highways, the first and the most important counter measure is to define the location of the road and design the road properly. For the last three decades, since Built-Operate-Transfer (BOT) approach has been in use, the snow drift situations of different alternative routes were started to be studied as scale model in wind tunnels in research laboratories under the same prevailing wind conditions recorded in the field conditions. The geometric and physical characteristics of the roads can be determined at the design stage according to findings of the model studies for snow drift problem, so the winter maintenance cost can be minimized.

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