Numerical Simulation of Snow Drifting Disaster on Embankment Project

Shouyun Liang, Xiangxian Ma and Haifeng Zhang
Key Laboratory of Mechanics on Disaster and Environment in Western China (Lanzhou University) /Ministry of Education, Lanzhou, P. R. China
Email: liangsy@lzu.edu.cn, maxxan04@lzu.cn, hai_feng2008@yahoo.com.cn

***Abstract*—Snow drifting is a typical natural disaster, and an increasing importance has been attached to its theory research and field observation for the sake of cold region engineering. Numerical simulation, as an efficient method of studying snow drifting, promises to be widely applied in this field. In this paper, the finite element method is used to simulate the wind velocity field. Selected upwind, downwind and middle part of a road as key comparison points, a quantitative analysis constructed of the influence of subgrade width, height and slope ratio on the wind velocity of embankment. The results showed that, under certain circumstances, the velocity of snow drifting demonstrated different function types of increase with the height and slope ratio of subgrade enhancing, and the influence of the height is greater than the slop ratio of subgrade, while the velocity of wind decreases with the width of subgrade increasing; the numerical values approximately agreed with the field observed results, but the numerical simulation is more sensitive to various forms of embankment. The numerical results can offer references for engineering construction when the region in which wind velocity is slower than the threshold velocity as snowpack area.**

***Index Terms* — embankment project, snow drifting disaster, numerical simulation, ANSY**

I. INTRODUCTION

Snow drifting is a typical natural disaster. The frequent occurrence of snow drifting has directly brought serious loss to industrial and agricultural production and people's life and property, baffling sight, blocking traffic, breaking electricity, leading industry and agriculture to go out of production and other hazards [1]. Therefore, an increasing importance has been attached to its theory research and field observation [2]. Sato et al. have brought forward turbulence model and other theories based on Eurler view and multiphase flow and Prandtl mixed length; Liston et al. have applied simple k-ε turbulence model to simulate accumulation process of snow according to the way in which the control unit is filled in by the information of the transporting capacities of particles of snow. In the study of road snow drifting disaster, foreign scholars mainly employ CFD to simulate the influence of snow fence on snow drifting distribution, and by taking account of suspension and saltation analyze the law of flow field transformation and snow distribution [3]. By using FLOW-3D, Thordarson [4] has simulated distribution and change of volume of the snow near road flow field and within the unit, and thereby simulated the movement of snow drifting. Xi and Ying et al. [5-6] have by employing bilateral flow theory simulated the flow field of snow drifting disaster through FLUENT software, and concluded the qualitative change of different subgrade flow field. Hu et al. [7] has applied ANSYS software to simulate the change of wind velocity field in order to discuss the impact of snow-sand blockings on subgrade snow, and thereby put forward sound setting and form of snow-sand blockings. Among these informed simulation research of snow drifting, there exists a lack of a qualitative study of the impact of blockings on flow field, and there runs short of considering the relation between engineering structures and snow drifting disasters. Taking the embankment project for example, the author of this paper has simulated its variation of wind velocity field through ANSYS, deeply analyzed every factor of embankment sections with different models, the quantitative relationship of wind velocity field, and the combined effects of each factor on wind velocity field, and achieved the objective of indirectly reflecting the graveness of snow drifting disasters.

II. MODEL DESIGN

According to related theory of aerodynamics, there existed a certain degree of relevance between accumulated snow and wind speed, furthermore, particles of snow bore a better following performance, therefore, the author has drew on the variation of wind velocity field to reflect indirectly the change of snow. A simulation experiment has constructed based on Fortran CFD of ANSYS, by adopting simple algorithm, N-S equation and k-e model [8-10]. And this conception has been proved feasible by the contrast of wind velocity field observations (Feb, 29th 2008) of Jinghe-yining (JY) railway embankment section (DK176+848) under construction with its simulation values (Fig.1). Besides, some simulation conditions of embankment sections have been given by referring to standards concerning railway and civil engineering techniques (Table I). Seeing that the wind vertical with road surface influences accumulated snow the most, the author has only taken account of the condition when the wind is vertical with

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Corresponding author, E-mail: liangsy@lzu.edu.cn

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road surface, leaving out account of the condition when the wind is oblique crossing and horizontal.

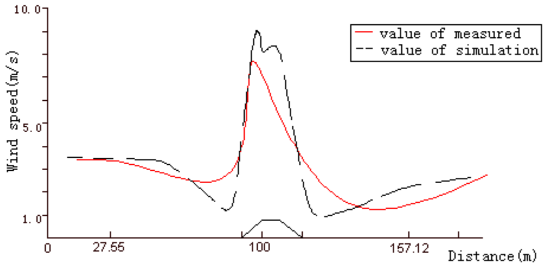

Figure 1. Comparison of wind speed of simulation and field measured of JY railway embankment section (DK176+848.555)

TABLE I.
PARAMETERS BASED ON SIMULATION

Condi-tion	Embankment Width (m)	Embankment height (m)	Slope ratio	Velocity (m/s)
1	9, 12, 15, 18, 24.5	4	1:1.5	9.4
2	9	2, 4, 8, 12, 13, 14, 15, 16, 17	1:1.5	9.4
3	9	4	1:1, 1:1.25, 1:1.5, 1:1.75	9.4

III. ANALYSES OF SIMULATION RESULTS

A. Impact of embankment width on wind velocity field

For subgrade with different width, their wind velocity fields are similar, in both of which wind velocity of the area with a certain distance to the foot of upwind slope is blocked, and thus declines drastically. The wind velocity reaches its minimum at the foot of the upwind slope, with airflow subsequently climbing the slope it increases to its maximum at the shoulder, and it reduces slightly in between, and then increases again at the shoulder of downwind slope (Fig. 2). The wind velocity of the area one meter from the foot of the downwind slope reduces almost to zero, thereafter a whirlpool comes into being, and wind velocity declines more or less, and then it would retrieve its former speed. Fig. 3 illustrates varied wind velocity (0.5 m above the surface) of road surface of different subgrade width, based on the key points of shoulder of upwind slope, in between, and shoulder of downwind slope. Regression analysis showed that the wind velocity of subgrade represents different function changes with the increase of subgrade width at the three points:

At shoulder of upwind slope:

$$V = -0.1114w + 16.228 \quad (R^2 = 0.9903) \qquad (1)$$

In between:

$$V = 0.0021w^2 - 0.0906w + 14.134 \quad (R^2 = 0.9907) \qquad (2)$$

At shoulder of downwind slope:

$$V = 0.0052w^2 - 0.2199w + 12.261 \quad (R^2 = 0.9926) \qquad (3)$$

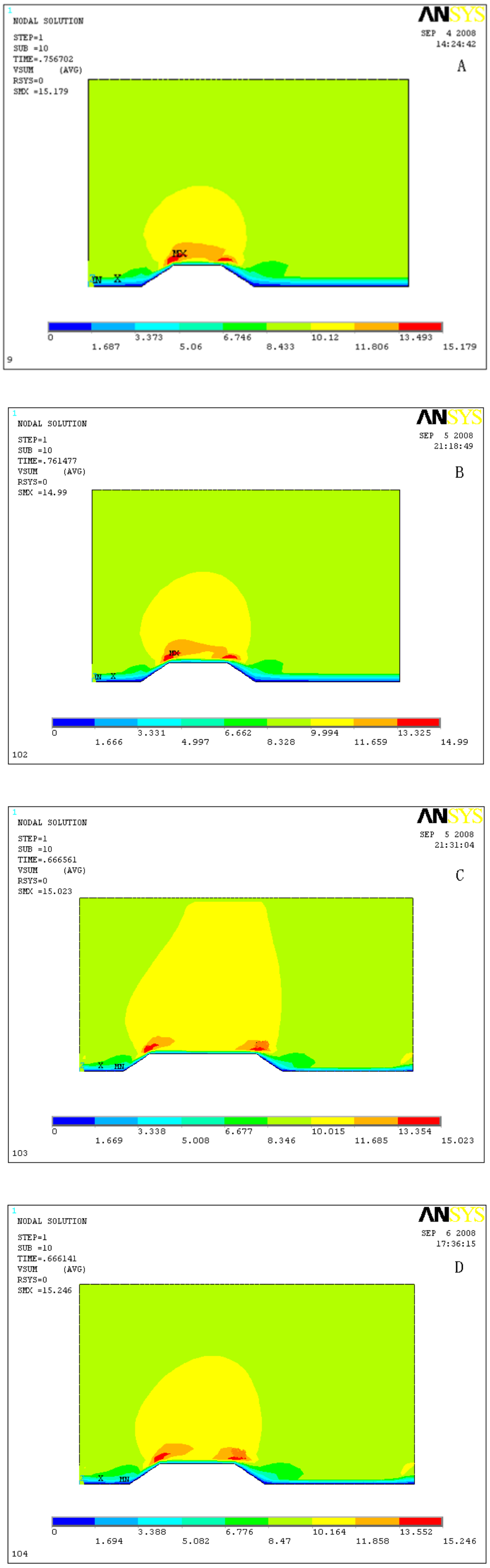

Figure 2. The contour of velocity with different embankment width (fig A-D: 9 m,12 m,15 m,24.5 m)

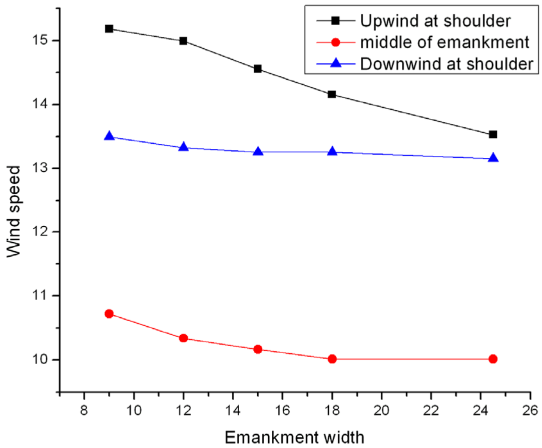

Figure 3. The relationship between changes of subgrade width and wind speed of road (0.5 m above pavement)

B. *Impact of embankment height on wind velocity field*

For subgrade with different height, their wind velocity field bears similarity, and even resembles with wind velocity field of subgrade with different width (Fig.4). Fig. 5 illustrates varied wind velocity (0.5 m above the surface) of road surface of different subgrade height, based on the key points of shoulder of upwind slope, in between, and shoulder of downwind slope. Regression analysis represented that the wind velocity of subgrade first increases and then decreases with the increase of subgrade height at the three points. With the 15 m being the dividing line, when the height is less than 15 m, the wind velocity has good relativity to quadratic curves. The law presents itself as follows:

At shoulder of upwind slope:

$$V = -0.0522 h^2+1.58127 h +10.52638 \quad (R^2 = 0.9581) \qquad (4)$$

In between:

$$V=-0.0439h^2+1.1205h+7.1518 \quad (R^2 = 0.9843) \qquad (5)$$

At shoulder of downwind slope:

$$V = -0.042h^2+1.4331h+9.1942 \quad (R^2 = 0.9994) \qquad (6)$$

When the height is more than 15 m, wind velocity begins to decline, first considerably and then gradually. The relativity of fitting curve reduces.

$$V = -0.0886h^2+2.2006h+7.2217 \quad (R^2 = 0.7877) \qquad (7)$$

$$V = -0.0731h^2+1.7991h+5.2242 \quad (R^2 = 0.7495) \qquad (8)$$

$$V = -0.1013h^2+2.5052h+8.0499 \quad (R^2 = 0.7913) \qquad (9)$$

C. *Impact of slope ratio on wind velocity field*

For subgrade with different slope ratio, the wind velocity fields distribute generally similar to above mentioned two situations (Fig. 6). Fig. 7 illustrates the wind velocity (0.5 m above the surface) of road surface with different slope ratio. We can see that, the wind velocity represents a linear decrease with the increase of slope ratio at the three points, in which the variation of wind velocity at shoulder of upwind slope can be formulated as:

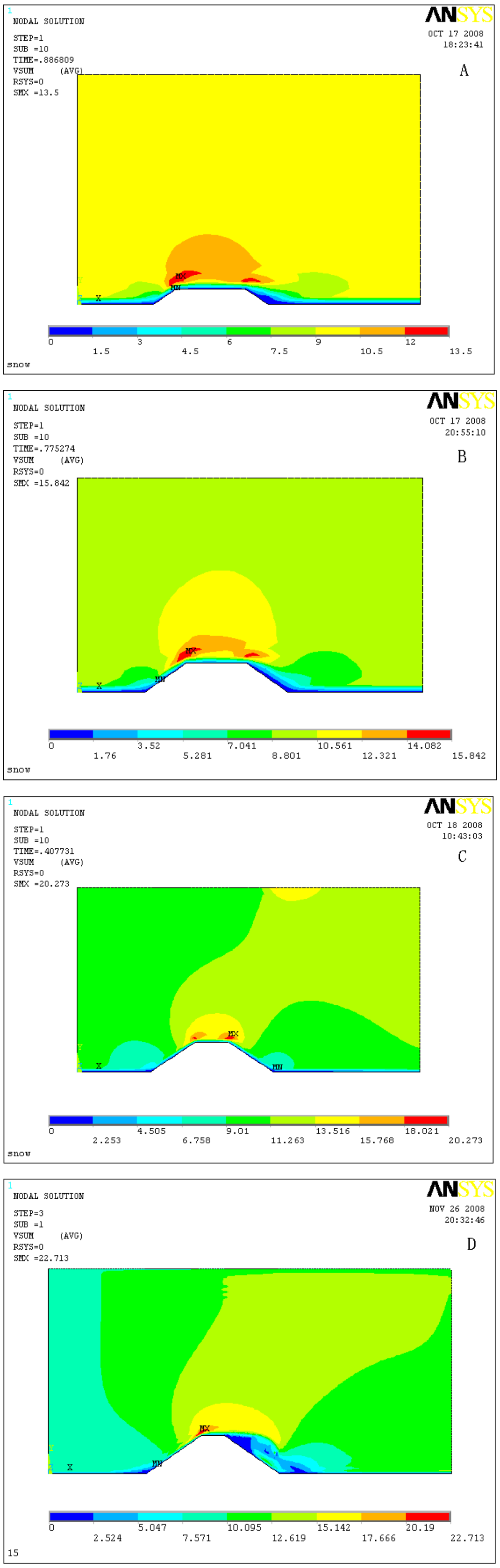

Figure 4. The contour of velocity with different height of road (fig A-D: 2 m, 8 m, 15 m, 16 m)

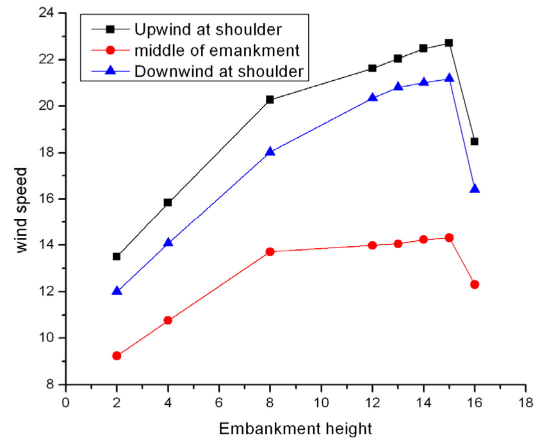

Figure 5. The relationship between changes of subgrade height and wind speed of road (0.5 m above pavement)

$$V=-105.89\tan\alpha^3+235.44\tan\alpha^2-167.33\tan\alpha+52.271 \quad (R^2 = 1) \qquad (10)$$

D. Comprehensive Analysis

In order to simultaneously study the combined effects of subgrade width, height, and slope ratio on wind velocity field of road surface, the author has adopted linear regression to calculate correlation coefficient of each factor with SPSS under a confidence level of 0.95.

At shoulder of upwind slope:

$$V=-0.089w+1.034h+3.795\tan\alpha+8.557 \qquad (11)$$

In between:

$$V=-0.052w+2.101h+2.875\tan\alpha+10.007 \qquad (12)$$

At shoulder of downwind slope:

$$V=-0.117w+3.24h+4.018\tan\alpha+5.34 \qquad (13)$$

From the formulation, we can see the wind velocity is negatively related to the subgrade width, positively related to the other two factors. All taking into consideration, the impact of subgrade height on wind velocity field is much more significant than that of the slope ratio.

IV. CONCLUSION AND DISCUSSION

Though embankment project just serves as a relatively ideal subgrade model for snow drifting disaster, we still can gain constructive knowledge from above research with regard to the relation between subgrade model and snow drifting disaster:

(1) With subgrade width increasing, the wind velocity of road declines in different functions: it changes the most drastically at the shoulder of upwind slope; next is at the shoulder of downwind slope; the last is the between part. For this reason any increasing or decreasing of subgrade width is not a significant factor leading to snow disaster on road. With subgrade height and slope ratio increasing, the wind velocity of road increases in different functions. However, the impact of subgrade height on wind velocity field is far bigger than that of slope ratio, yet when subgrade height is more than15 m. the wind velocity of road reduces instead. This dividing line of 15 m coincides with that of h=15.1 m in Wang's (2001) wind tunnel experiment [1]. Thus, there exists an appropriate subgrade height from the perspective of snow on road.

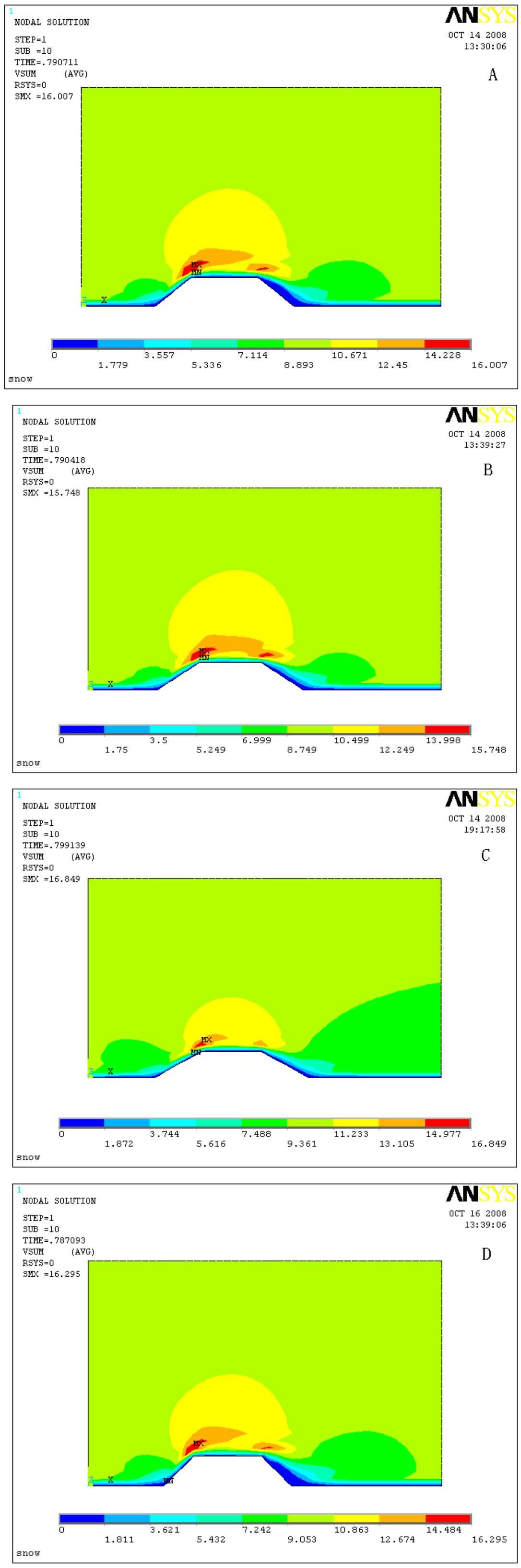

Figure 6. The contour of velocity with different slope of ratio(fig A-D: 1:1,1:1.25,1:1.5,1:1.75)

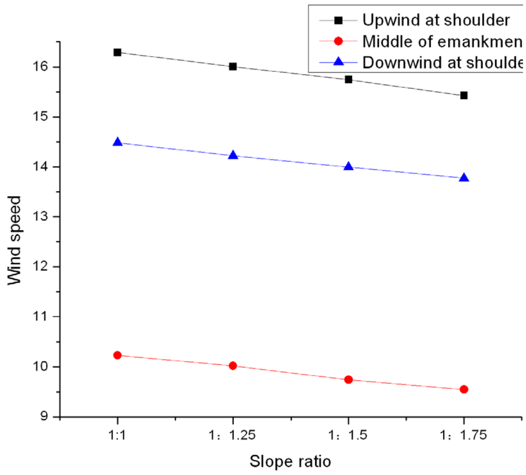

Figure 7. The relationship between changes of slope ratio and wind speed of road (0.5 m above pavement) pavement)

(2) The conception of considering sugrade width in this simulation research has consulted relevant railway and civil engineering standards, so a study of its wind velocity field can provide some guidance to practical practice. Comparison shows that the simulated values agree well with the observations. The simulated values seem more sensitive to the change of subgrade design parameters, whereas the observations would be frequently affected by the wild weather, terrain and other factors. This renders the system more complicated. If we regard the area in which wind speed is less than the starting speed in the figure of simulated wind velocity field as snow area, this research can offer references for prevention and control of snow drifting disaster in engineering aspect.

(3) This research is based only on three representative points of a road and the wind speed of 0.5 m above the road, therefore, the investigation of wind velocity variation on a road remains to be carried further in depth by taking more data on points and heights, improving the precision and depth of research.

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