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Study of Sand Control Effects of Nylon Net Fences

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Abstract: Field monitoring and wind tunnel simulation of sand control effects of nylon net fences showed that these fences are not only more effective in sand-blocking, but also can divert the sand flow. Such function widens its application range and also provides an effective way to control moving sand in Gobi area. Nylon net fence, more effective than wooden fence, is of two types, namely dense type with an optimal porosity ranging from 40-50%. This type of fence can provide protection for downwind area up to 30 times the height of fence. Under medium wind velocity condition (V = 10~15 $m.s^{-1}$), the sand-blocking rate can exceed 70%; even under very strong wind condition (V> 18 $m.s^{-1}$) the sand accumulation rate can exceed 50%. Nylon net fence also deflects the moving sand, with a critical angle of 45°. If the angle between the fence and the prevailing wind direction exceeds 45° its sand diversion efficiency will be reduced.

Key words: Nylon net fence, sand control effect, wind tunnel simulation

Nylon net fences have been widely used for the establishment of enclosed pastures in some countries. In recent years they were first used as one of the new sand barriers in the Mogao Grottes district (Ling *et al*., 1996) and then used to control sand encroachment on the oil-transporting highway in the Tarim Desert (Wang *et al*., 1999). Because these nets have low cost, long life, better sand control effect and are easy to use, they have extensive prospects of controlling sand behaviors in the industrial and mined areas, along the roads and other sites of historical importance. In many practical applications, it is essential to control the flow structure to fit a specific need. Porous net fences have been widely used as a turbulence manipulator. They have also been used to reduce the flow velocity or abating wind erosion of small particles (Kim and Lee, 2001; John *et al*., 2003; Bofah and Alhinai, 1986; Borges and Viegas, 1988; Lee and Lim, 2001; Alhajraf, 2004). Most previous studies on porous fences concentrated on the shelter effect. They put emphasis on the wind velocity reduction and the turbulent momentum of the wind fence wake (Lee *et al*., 2002; Packwood, 2000; Park and Lee, 2003; Judd *et al*., 1996; Gupta and Ranga, 1987; Lee and Kim, 1998, 1999; Fang and Wang, 1997; Seginer, 1975; Perera, 1981; Papesch, 1992). Through field monitoring and wind tunnel simulations of the sand control effects of nylon net fences, this paper deals with the optimization design of sand control engineering structure of nylon net fences and thus lays a theoretical basis for their application.

Field Monitoring of Sand Control Effects of Nylon Net Fences

Mogao Grottoes in Dunhuang of Gansu province in China have long been severely

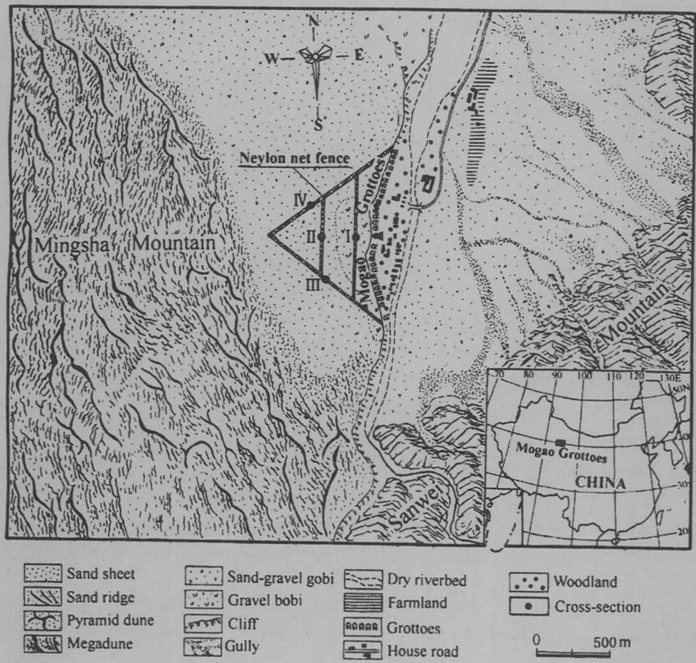

Fig. 1. Location of nylon net fences and wind rose.

suffering from sand damages due to lack of effective sand control measures. In order to control sand damages to Mogao Grottoes, the Lanzhou Institute of Desert Research under the Chinese Academy of Sciences, in cooperation with Getty Conservation Institute of America, used nylon net fences as sand barriers in the Grottoes district in recent years. According to the district's sand movement characteristics caused by three wind directions (Fig. 1), A-shaped nylon net fences were designed. The apex of the A-shaped nylon net fences pointed towards the prevailing wind direction (W) aiming at cutting off the sand supply from the Mingsha Mountain from the secondary wind direction (SSW) and at the same time deflecting the sand flow from the prevailing wind direction (W), thus changing the single sand-blocking function of the sand fence. Two parallel transverse barriers of the A-shaped nylon net fences were designed to avoid sand accumulation.

Monitoring Results

Monitoring of sectional sand accumulation shapes

Figure 2 shows the monitoring results of sectional sand accumulation shapes, of which the sand-blocking functions of the section I and section II of the two parallel transverse barriers of the A-shaped nylon net fences are illustrated in Fig. 2a and 2b. As can be seen in these two figures, the sand accumulation shape was growing continuously (from east to west), but the growth rate gradually declined. This shows that the main sand flow moves from the

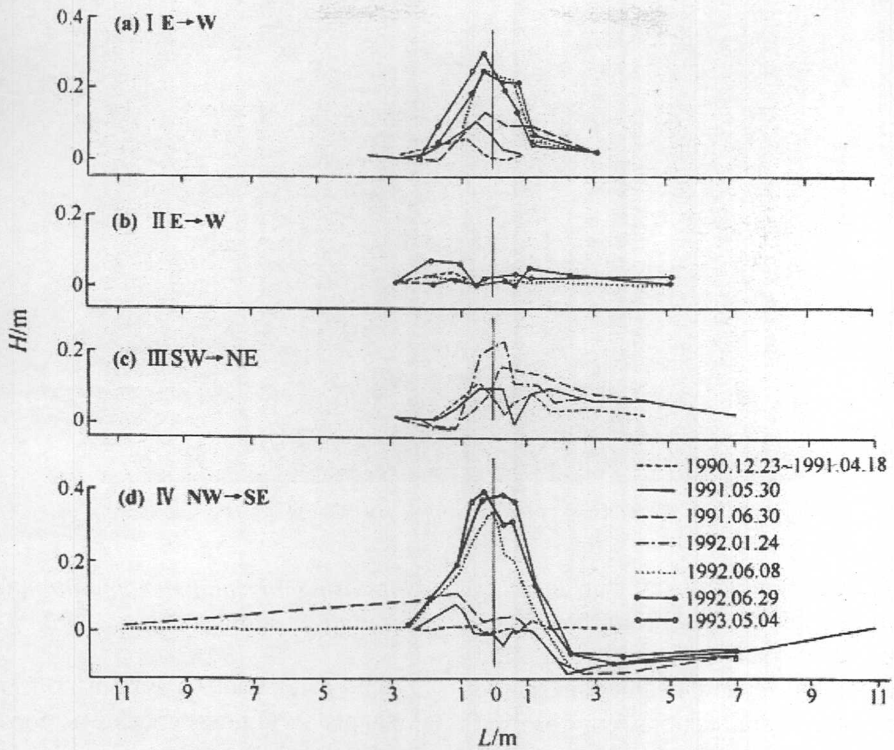

Fig. 2. Sand accumulation shape at different sites ahead of and behind the A-shaped nylon net fences.

east to west due to the reverse transportation of sand deposited on cliff face and cliff top surface by strong east winds. On the other hand, the sand accumulation shape of section changed little and its absolute value was also small. This shows that both the east and west walls of section II of the two parallel transverse barriers of the A-shaped nylon net fences can effectively block the encroaching sand flow and the stable gravel surface in the protected district can only produce limited sand materials. Section III indicates that wind erosion is noticeable outside the fence and there is much accumulated sand at the base of the fence and on its inner side. This reflects erosion-deposition processes caused by southerly winds whether westerly winds result in lateral diversion of moving sand. Under the action of westerly winds, the lateral diversion rate of moving sand is 35% outside the fence and 15.89% inside the fence. Section IV shows the monitoring results of sand accumulation processes caused by westerly winds. The calculated results show that on the side of Section IV, the westerly wind-induced maximum annual sand transport rate was 10.483 m^3. If sand transport continues at this rate, the existing fences will be completely buried by sand in a year. However, since the region has three different wind regimes with different frequencies, intensities, durations and seasonal changes, the transport and deposition

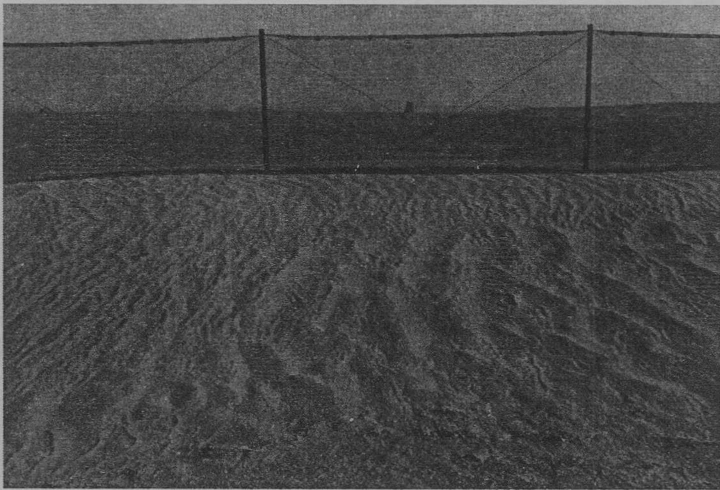

Fig. 3. The relationship between ripple strikes and fence orientation.

process of sand materials exhibit an alternate feature in time and space. From the section IV in Fig. 2d it can be seen that its sand accumulation range and height ranked the first among the several sections. Wind erosion was significant within 20 m ahead of and behind the fence, especially inside the fence the ground surface was always in a deflation state. Because the section IV of the fence (Fig. 1) resumes a NE-SW trend, especially the effect of cliff topography, there were no sufficient sand sources present in NNE and NE wind directions. Furthermore, due to strong wind force, the mean lateral diversion rate of the sand that accumulated outside the fence was 34% or so, but it could reach 56.33% between April and May of a year. Such lateral diversion of sand flow was even more conspicuous inside the fence. On an average, it was 57.51% due to the influence of stronger ENE winds. Lateral diversion of sand flow can also be demonstrated by the ripple strikes of sand accumulated behind the fence, namely the ripple strikes are perpendicular to the fence orientation (Fig. 3).

Monitoring of sand accumulation rate on the plank roads of the Mogao Grottoes

The sand control system consisting of A-shaped nylon net fences was constructed in the late November of 1990 and the monthly changes of sand weight accumulated in the sand-collecting boxes on the plank roads of the Mogao Grottoes (Fig. 4) were monitored. It can be seen that after the nylon net fences were constructed sand accumulation rate on the plank roads of the Grottoes significantly decreased. Roughly it decreased by about 60% as compared to the monthly sand accumulation rate on the plank roads before the fences were erected. It might be said that before the cliff face was stabilized by chemicals, the changes in sand accumulation rate in front of the grottoes cannot truly reflect the sand control effect of the nylon net fences. Because the strong wind erosion caused by eastern winds can lead to the downward slipping of sand accumulated for a long time and thus may result in sand deposition in front of the

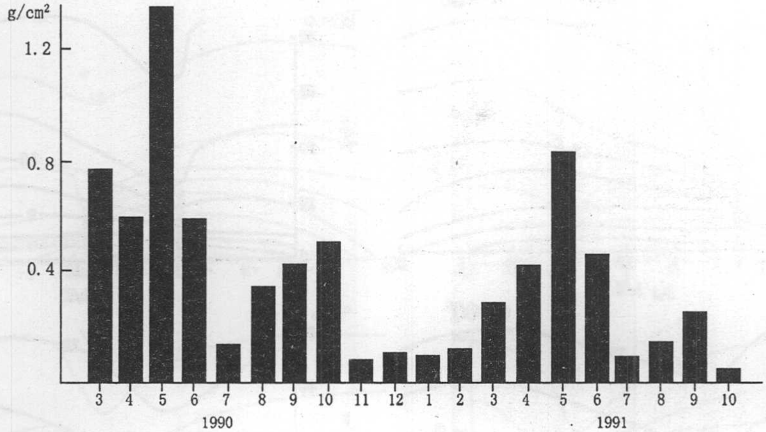

Fig. 4. Monthly changes in sand accumulation rate on the plank roads in front of the Mogao Grottoes.

grottos. Such changes are mainly manifested in the decrease or disappearance of yellow-colored sand accumulated on the cliff top and at the cliff face and the increase in coarse sand in the sand-collecting boxes in front of the grottoes.

Wind Tunnel Simulated Experiments on the Sand Control Effects of Nylon Net Fences

Experimental content

According to sand control engineering requirement, the sand-blocking and sand-diverting effects of the nylon net fences under the condition of different porosities and different angles between the fence and the prevailing wind directions were simulated in the wind tunnel. These net fences are 1.2 m in length, 15 cm in height and 2 mm in thickness. The porosities and included angles selected in the simulated experiments are β = 50-55%, 40-45%, 30-35% and 20-25% with 30°, 45°, 60° and 90°, respectively. The wind velocity selected is V_∞ = 11 m/s.

Experimental results and discussion

The experimental results are shown in Figs. 4-7. In the experiments, the porosities of the nylon net fences gradually decreased from 50-55% to 20-25%, with the angles between the fence and prevailing wind direction equaling 30°, 45°, 60° and 90° as flow field longitudinal profile condition. According to the strength of wind speed varying, the determinations were conducted in eight redistributed new energy zones, namely five new energy zones immediately above the surface plus-minus- plus (before the fence)-minus-plus zones (behind the fence), and two retarded and vortex retarding zones at the top ahead of and behind the fence, and one elevated flow-concentrating and accelerating zone below the top of the fence (the detailed diagrammatic signs in 5, and others are the same to this). The distinction between the dense and porous fences lies in the three aspects, namely the latter has better flexibility, stronger sand penetrability and a weak accelerating zone behind the fence. From Table 1 it can be seen that the nylon net sand control effects show that the nylon net fences directly blocked about 95% of sand moving towards the Mogao Grottoes by westerly winds and the sand volume deposited in front of the grottoes during night decreased by 80%. The lateral diversion percentage of sand accumulated by the prevailing winds outside the outer nylon net fences on an average reached 35%, while the lateral diversion percentage of sand accumulated inside the fences by the easterly wind was 57.71% and by the westerly wind was 15.89%. This shows that the sand control effect of the fences changes with season. The engineering protection exhibits some new characteristics of sand transportation by wind, such as the lateral diversion of moving sand caused by the fences and the co-existence of wind deposition and erosion processes in front of the grottoes. This has a very important theoretical and practical significance for the study of the region's sand control problem. Experiments on wind tunnel results show that nylon net fences are a better sand control material than wooden fences. Their optimal porosity to block sand material is 40-45% and they can provide protection in downwind direction up to 30H or more. However, their sand-blocking efficiency varies with the angle between the fence and the prevailing wind direction, with a critical angle of 45°. If this angle exceeds 45°, the diversion efficiency of moving sand will be reduced and thereby lead to the formation of sand dike gradually moving away from the fence on the leeward side, which together with the nylon net fences are responsible for the diversion of sand flow. However this is a problem, which may further be studied through adoption of feather-like fences.

References

Alhajraf, S, 2004. Computational fluid dynamic modeling of drifting particles at porous fences. *Environmental Modelling & Software* 19: 163-170.

Bofah, K.K. and Alhinai, K.G. 1986. Field tests of porous fence in the regime of sand land wind. *Journal of Wind Engineering and Industrial Aerodynamics* 23: 309-319.

Borges, A.R. and Viegas, D.X. 1988. Shelter effect on a row of coal piles to prevent wind erosion. *Journal of Wind Engineering and Industrial Aerodynamics* 29: 145-154.

Fang, F.M. and Wang, D.Y. 1997. On the flow around a vertical porous fence. *Journal of Wind Engineering and Industrial Aerodynamics* 67&68: 415-424.

Gupta, V. and Ranga Raju, K. 1987. Seperated flow in lee of solid and porous fences. *Journal of Hydraulic Engineering* 113: 1264-1277.

John, D., Wilson., Yee, E. 2003. Calculation of winds disturbed by an array of fences. *Agricultural and Forest Meteorology* 115: 31-50.

Judd, M.J., Raupach, M.R. and Fininigan, J.J. 1996. A wind tunnel study of turbulent flow around single and multiple windbreaks, part I: velocity. Boundary-Layer Meteorology 80 : 127–165.

Kim, B.K .and Lee, S.J. 2001. Hole diameter effect on flow characteristics of wake behind porous fences having the same porosity. *Fluid Dynamics Research* 28: 449-464.

Lee, S.J. and Kim, H.B. 1998. Velocity field measurements of flow around a triangular prism behind a porous fence. *Journal of Wind Engineering and Industrial Aerodynamics* 77&78: 521-530.

Lee, S.J. and Kim, H.B. 1999. Laboratory measurements of velocity and turbulence field behind porous fences. *Journal of Wind Engineering and Industrial Aerodynamics* 80: 311-326.

Lee, S.J. and Lim, H.C. 2001. A numerical study on flow around a triangular prism located behind a porous fence. *Fluid Dynamics Research* 28: 209-221.

Lee, S.J., Park, K.C., Park, C.W. 2002. Wind tunnel observations about the shelter effect of porous fences on the sand particle movements. *Atmospheric Environment* 36: 1453-1463.

Ling, Y.Q., Qu, J.J., Fan, J.S., Li, Y.H. and Agner, N. 1996. Analysis of the sand control engineering effects on the cliff top of the Mogao Grottoes. *Journal of Desert Research* 16: 13-16.

Liu, X.W. 1995. *Experimental Blown Sand Physics and Sand Drift Control Engineering*. Science Press, Beijing. 210 pp.

Packwood, A.R. 2000. Flow through porous fences in thick boundary layers: comparisons between laboratory and numerical experiments. *Journal of Wind Engineering and Industrial Aerodynamics* 88: 75–90.

Papesch, A.J.G. 1992. Wind tunnel tests to optimize barrier spacing and porosity to reduce wind damage in horticultural shelter systems. *Journal of Wind Engineering and Industrial Aerodynamics* 44: 2631-2642.

Park, C.W. and Lee, S.J. 2003. Experimental study on surface pressure and flow structure around a triangular prism located behind a porous fence. *Journal of Wind Engineering and Industrial Aerodynamics* 91: 165-184.

Perera, M.D.A.E.S. 1981. Shelter behind two-dimensional solid and porous fences. *Journal of Wind Engineering and Industrial Aerodynamics* 8: 93-104.

Qu, J.J. 1993. Preliminary study of sand control effect of Nylon net fences in the top district of the Mogao grottoes. *Arid Zone Research* 3: 20-25.

Seginer, I. 1975. Atmospheeric-stability effect on wind break shelter and drag. *Boundary-Layer Meteorology* 8: 383-400.

Wang, X.M., Chen, G.T., Han, Z.W. and Dong, Z.B. 1999. Effect analysis of mechanical sand control system along the Tarim Desert highway. *Journal of Desert Research* 19: 120-127.