

Feasibility Research on Windbreak Net for Coal Yard

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Abstract: Based on the investigations of the coal dust pollution status of the coal yard in Qin Huangdao port and referred to many dustproof techniques, this article indicates that compared with several dust-removing measures, windbreaks are effective barriers that help reduce or redirect wind to restrain the coal dust. Then the dustproof principle is analysed accordingly, and numerical simulation of air flow distributing after windbreak net is taken to obtain the main parameters of the net and the result suggests using windbreak net as main approach, combined with dry or wet method, as well as shelterbelt, and the best scheme of designing the windbreak net is put forward.

Keywords: energy, Windbreak net; Numerical simulation; CFD; Coal yard; Dust pollution; Dustproof

1. INTRODUCTION

Nowadays, the prevention of coal dust pollution in coal pile field is staring people in the face along with the enhance awareness of environmental protection. According to the current condition of open-air coal yard, it is a right choice to adopt international prevailing windbreak net to prevent coal dust pollution.

2. GENERAL SITUATION OF THE PROJECT

Qin Huangdao port is the biggest energy sources export and integrated international trade port, and is one of the biggest coal export port where the coal dust pollution is serious (e.g. Fig. 1). Strong and severe winds are one of the biggest problems the open-air coal or ore yard have to face. Approximately one kilometre in circumference is residential area, office service area of the port and scenic spot of Mount Nanshan, and the coal dust descent on the dwelling place, clothings, ground and even enter into respiratory tract. The pollution caused by the dust bring along inconvenience to people and reduce the quality of life. Although the coal yard already has some dust-removing facilities such as strap cover, windshield board, high-pressure adjutage and dust catcher, it is still far from the demand of air quality standard.



Figure 1: Current condition of open-air coal pile in Qin Huangdao port

3. THE CURRENT STATUS OF THE DUST PREVENTION TECHNIQUE LEVEL AT HOME AND ABROAD

In recent years, as the production establishment of the coal or ore stevedore port especially some large coal port of single purpose renewed rapid, the dust prevention has made certain progress. Although exists many problems, the pollution control of the dust source is effective on the whole. But some middle or small coal or ore port, particularly small port and old dock, the pollution is serious because of stevedore techniques and facilities are obsolete, lack of dustproof equipment.

The main measures of dustproof at home and abroad are as follows: dry method, wet method, the combination of the two methods, shelterbelt method, windbreak net method and so on.

A. Wet method of dustproof: spraying and sprinkling chemical medicament to dust source so as to increase viscosity and weight of dust to prevent dust pollution. It is efficient but it has high price, and is easy to freeze because of the low temperature in the north. The pile field of port in seaside city is dried easily after watering due to the monsoon. So using only this method cannot meet the prevention request.

B. Dry method of dustproof: enclose main dust source as far as possible, assistant with some dust collection facilities. For example, using sealing construction, dust collection facilities, covering and compacting etc. It can get good effect on part of the field and is not limited by water and seasonal weather. Compared to wet method, it has complex fixing, high cost and limited ability. It can be the supplement of wet method.

C. Shelterbelt method: Its mechanism is to lower the wind above the pile, and diminish the dust produced by piling, assembling and disassembling. The shelterbelt can not only prevent the dust, also beautify the environment and reduce the noise, has both social and environmental benefit. As shown in figure 2, the trees around the coal yard can also take certain effect on

restraining the coal dust. But the most coal, ore piles and ports are set up on the edge of the city, lack of ground brings difficulties to popularise. So only the shelterbelt is definitely unpractical and cannot settle the dust problem totally.

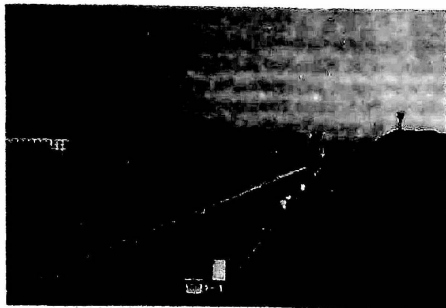


Figure 2: the trees around the coal yard acted as shelterbelt to restrain the coal dust

D. windbreak net method : After setting up windbreak net around the coal, ore pile field in the port, the wind pass through the net, the wind pressure changes above the pile, and the streamlines of the wind change prominently. The velocity of the wind reduces below the dust velocity after setting the net, so as to restrain the dust. It is applicable for the conditions that have large dust pollution source, and require preventing the wind and reducing coal dust transport during the whole day.

Application of modern and effective windbreak net can offer long-term benefits by guaranteeing protecting port from pollution with once investment and lower repair or management expenses. windbreak net is the project of environmental protection so that it has not management property, but it can obtain indirect income by lessen the coal dust loss during piling. The project investment can callback in 8 or 10years while it can use more than 20 years. And the usage of windbreak net can improve the air quality around the field. Compared with other dust-removing methods, Windbreak net has economic benefit, environmental benefit as well as social benefit simultaneously. Thereby the research works are carried on and the windbreak nets are actively put to use all over the world.

4. DUSTPROOF SCHEME

The port should take whole dustproof scheme that has one or several dustproof techniques as main measure, and other measures assistant. Therefore this research suggests using windbreak net as main approach, combined with strap cover, windshield board, high-pressure adjutage, dust catcher and shelterbelt, so as to deal with the coal dust synthetically.

5. DUSTPROOF MECHANISM

A great deal of tiny particle enters into the wind and forms the dust emission process of the coal dust by force of strong wind and convolute of whorl field, the air flow keeping the dust passes the pile field so as to decelerate the wind, reduce the kinetic energy of turbulence and largen the relative function of gravity, except continuing drift and diffusion action, the dust in the air flow starts depression in succession, those forms the drift, diffusion and depression process of the coal dust.

The amount of the dust emission has a close relation with wind speed, kinetic energy loss and wind turbulivity. The wind passes through the net, reduce wind speed and turbulence, minish the vortex of approach flow effectively, and depress the cut stress above the pile so as to restrain the dust.

6. NUMERICAL SIMULATION AND ANALYSIS OF DUSTPROOF EFFECT

Windbreak net effectiveness is a function of the height, its density or porosity, and other parameters. So numerical simulation is taken to obtain the right design parameters of the windbreak net by CFD software. Along with the development of CFD-computational fluid dynamics, traditional wind engineering has been continuously break through the restrict of wind tunnel experiment which is operose and wastes of time. The emulation using CFD software avoid the complicated process of analytical solution and error caused by lack of experience and data in traditional method. Numerical simulation of the coal pile field will provide correct foundation to design and construction of the windbreak net for next step.

6.1 mathematics model and boundary condition

With regard to the size 900×600m of the coal yard, and the pile height 17.1m, L mode windbreak net is set to shield NE,SW prevailing winds according to weather information and pollution status in this scheme. (as shown in figure 3)

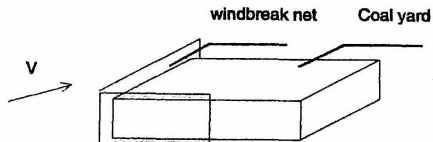


Figure 3: Physical model

Steady and conservative form Reynolds Averaged Navier-Stokes is adopted in the calculation:

$$\frac{\partial u_i}{\partial x_i} = 0$$

$$\frac{\partial}{\partial x_j}(\rho u_i u_j) = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j} \left[\mu \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3} \delta_{ij} \frac{\partial u_k}{\partial x_k} \right) \right] + \frac{\partial}{\partial x_j} (-\overline{\rho u_i u_j})$$

Reynolds stress item should be handled approximately when calculated by Reynolds Averaged Navier-Stokes equation. Using Boussinesq assume, the relation between Reynolds stress and average velocity grads is as follows:

$$-\overline{\rho u_i u_j} = \mu_t \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) - \frac{2}{3} \left(\rho k + \mu_t \frac{\partial u_k}{\partial x_k} \right) \delta_{ij}$$

To close the turbulence equation, adopt $k-\varepsilon$ two-equation model, when the flow is not compressible and not take account of source item:

$$\frac{\partial}{\partial x_j}(\rho k u_j) = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + G_k - \rho \varepsilon$$

$$\frac{\partial}{\partial x_j}(\rho \varepsilon u_j) = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon} \right) \frac{\partial \varepsilon}{\partial x_j} \right] + C_{1\varepsilon} \frac{\varepsilon}{k} G_k - C_{2\varepsilon} \rho \frac{\varepsilon^2}{k}$$

G_k is the response item from turbulence energy k which caused by average velocity grads, $C_{1\varepsilon}$ 、 $C_{2\varepsilon}$ 、 σ_k and σ_ε are all constant.

$$C_{1\varepsilon} = 1.44, C_{2\varepsilon} = 1.92, \sigma_k = 1.0, \sigma_\varepsilon = 1.3$$

$$\text{turbulence viscosity } \mu_t = \rho C_\mu \frac{k^2}{\varepsilon}$$

$$\text{constant } C_\mu = 0.09$$

The simulation adopts segregated solver, implicit formulation and steady flow. The fluid material is air. The windbreak net use porous jump as internal surface boundary, and the velocity inlet is provided by atmosphere boundary layer exponential rate. It is described as $v = v_1 \left(\frac{h}{h_1} \right)^n$ m/s, in which h_1 、 v_1 is referenced height and the velocity of that height, and this boundary is achieved by UDF (user defined functions). The outlet use completely developed outflow boundary. The top and two sides of the whole field adopt symmetry boundary, which is equivalent to free-slip wall, and the ground set no slip wall boundary.

6.2 Simulation of main characteristic parameter

The design for the windbreak net project is affected by lots of complicated factors, such as local weather condition, landform, the size of the field, the shape of the pile, the distribution of wind frequency and so on.

a) The mode of windbreak net

The windbreak net around the coal yard is usually categorized by setting in prevailing winds and around

the field. The choice depends on the size and shape of the field and the wind frequency distribution of the area.

According to the wind frequency distribution, the prevailing winds in the area of Qin Huangdao are NE whose frequency is 10.27%, SW is in the second place whose frequency is 8.75%. And the average wind speed is 4.44m/s of NE direction during one year. Therefore, as illustrated in picture 2, L mode windbreak net is set up in the coal yard, and section plane of the velocity field above the coal pile is presented in figure 4 which is derived from 3D numerical simulation when the net is set by 1.2 times height of the coal pile:

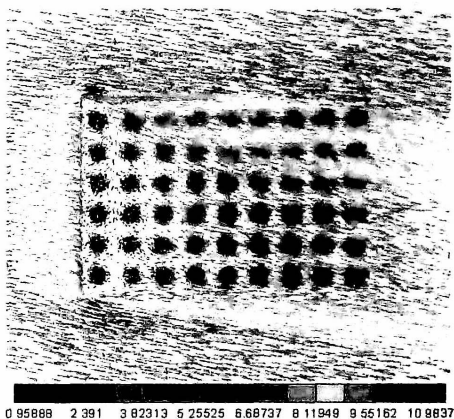


Figure 4: section plane of the velocity field

The windbreak net only set in windward side cannot satisfied environmental criterion that is increasingly strict owing to relatively poor effect of single net which can only shield off the air flow in only one wind direction. According to the pollution of the coal yard, setting the net around the field is more effective in two obvious wind direction, and in addition, taking account of economic factor, two L mode windbreak net could be set up in the field which mainly shelter NE and SW direction. Width of the net can be 630m that entirely shelter the coal yard of 600m widths; the length can be set regarded as the landform.

b) The porous rate of the windbreak net

The porous rate is the structural indication, which is the ratio of infiltrate area and total area and is an important parameter when design and process the windbreak net. The shield effect of entity windbreak wall should not better then the one that has porous rate. Several different porous rates are simulated by CFD method, and the result shows that 45% is applicable, it is because large backflow come into being between the net and coal pile, and press fluctuate enlarges due to reduced pervading flow which passes the windbreak net.

c) The height of the windbreak net

The height of the windbreak net lies on the height of the coal pile, the size of the coal yard and the request of air quality, accordingly the coal yard must be set in the region that is shielded by windbreak net effectively. 2D flow field is simulated when the net height (L) is from 1.1-2 times of the pile (H), the porous rate is 45%, the distance between net and pile is 20m, and the velocity-inlet is 10m/s, the result at the point farthest from the net above the pile is shown in fig.5 and fig.6:

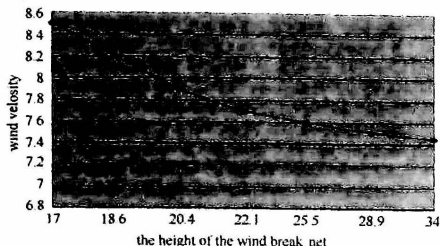


Figure 5: the relation between wind velocity and the height of the net

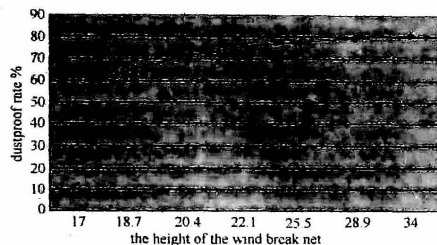


Figure 6: the relation between dustproof rate and the height of the net

As expressed in the fig.4 and fig.5, when $L=1-1.5H$, the height is in direct proportion with dustproof effect, the trend turn slow above 1.5H. Besides, as the net getting higher, the vortex behind the net is more obvious which can weaken the dustproof effect. So the height should be 1-1.5H. In view of both economic factor and dustproof effect, this scheme adopts $L=1.2H$.

d) The distance between windbreak net and piles

The windbreak net is usually set along the side of the pile field. As the coal yard has many coal piles, the windbreak net could be established to adjust measures to local conditions. And it is regulated in Japan that the distance between windbreak net and piles should be controlled in 1-1.5H. Otherwise, it is necessary to have enough space for the bracket of the net, hence 15-20m is applicable for this coal yard, and

there should have proper adjustment in terms of the condition during construction.

e) Trapezoid base

It can be seen in pic.7, a trapezoid base is added at the bottom of the net which have good effectiveness. It is because the trapezoid base has the function of guiding the air flow which can lead the wind direction upward and form an air curtain, so that the wind speed after the net is weakened slightly. So it is practicable for this project.



Figure 7: velocity field when added trapezoid base

After the main parameters are confirmed, the best scheme is obtained by 3D simulation, the velocity field is manifested as fig.8, from which can be seen that after setting up the windbreak net, part of the airflow pass through the net into the shelter region, the rest bypass upwards the net, which can obviously reduce wind speed and turbulence, and reduce the vortex of approach flow effectively so as to restrain the dust.

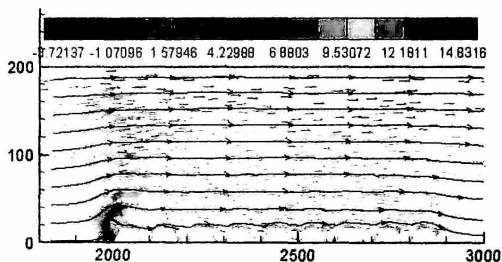


Figure 8: velocity field of the best scheme

6.3 Analysis of dustproof effect

Pic.9 and pic.10 indicates that the flow passing the net give rise to accelerating wind owing to circumfluence and there has a low wind region behind the net. The flow speed up before each pile and went round the pile, the wind slows down a bit when pass the surface of the pile, then entry the area between the pile, the wind slow down rapidly and turbulent eddy come forth. While dustproof rate has opposite change, average of which is about 80%, so that the windbreak net has good effect for coal dust prevention.

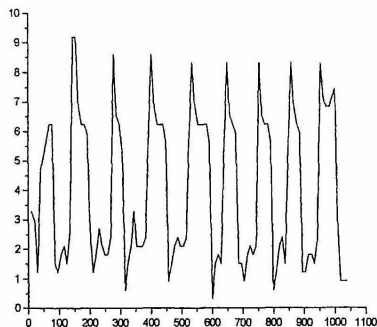


Figure 9: The velocity above the coal pile

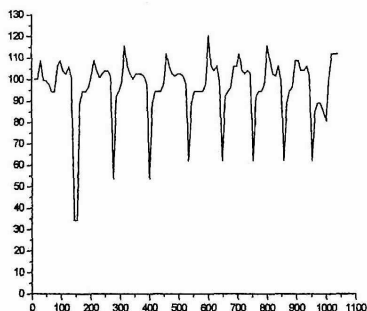


Figure 10: Dustproof rate above the coal pile

7. CONCLUSION AND SUGGESTION

- I. The port would take whole dustproof scheme which has one or several dustproof techniques as the main measures, and assisted with some other measures. Therefore this research suggests that using windbreak nets as the main approach, combined with dry or wet method and

shelterbelt, the coal dust problem will be solved synthetically.

- II. Based on absorbing and summarizing the research work of windbreak net at home and abroad, numerical simulation has been taken in allowable time and considering influencing factors as much as possible, and from which obtains the right design parameters for the windbreak net.
- III. The design of the windbreak nets project is affected by lots of complicated factors, such as local climate, landform, size of the field, shape of the pile, distribution of wind frequency and so on. It is suggested from simulation, two L mode nets are set to shield NE,SW prevailing winds, the porosity rate was 45%, the height is 1.1~1.3 times of the coal pile, the distance between nets and piles is 15~20m, and a trapezoid base is added at the bottom of the nets. Average dustproof rate is about 80% by means of CFD method, so that the windbreak net has good effect for coal dust prevention.

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