Optimization of Design Schemes for Layout of Windproof Net under Environmental Conditions

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Abstract. To improve the applicability of designing scheme of windproof net parameters, according to the existed research results and years of design experience, this essay comes up with the method to optimize the scheme of plane layout of windproof net according to the local environmental conditions of each project site which includes the conditions of weather, field nets and terrain as well as the scale of yards. The method will be verified through numerical simulation calculations.

Introduction

In China, there has been a trend that coal is transported from western areas to eastern areas or from northern parts to southern parts and the amount of imported ore increases drastically. Under this situation, ports of bulk cargos have been driven to develop rapidly, whereas atmospheric environment has been polluted to different extent. The dust pollution caused by stacking bulk cargos in yards is the most serious. Dust will accumulate on cargos and lead to dust pollution within a large area when cargos are dry and it is windy in large yards outdoors [1]. The amount of dust emission in a yard of bulk cargos is mainly dependent upon wind speed inside the yard [2] and windproof mechanism of windproof net. Windproof nets are generally set up around yards of bulk cargos to reduce the wind speed and amount of dust emissions inside the yards by improving flow field of wind and thus decreasing the wind speed [3]. Windproof nets have become popular among numerous Chinese ports and power generation enterprises over the past few years because they consume no power and require no cost of operation. Gradually, they will be the mainstream measure for suppressing dust in large ports of bulk cargos or yards behind power plants in the future. In China, projects of windproof nets have covered important ports and logistics bases of several provinces, including Heilongjiang, Liaoning, Hebei, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong and Guangxi.

Existing Research Findings

In China, researchers have begun to examine windproof nets relatively late [4]. Through years of test, research and engineering application, design of windproof nets, including their parameters and structures, has become quite mature. However, it is still necessary to further explore and optimize design schemes for parameters of windproof nets, including windproof board, layout, height and porosity. At present, there have been more scientific methods for determining following parameters:

(1) Pattern of Windproof Net

Currently, windproof nets are mostly butterfly-shaped, because butterfly-shaped windproof net is far more rigid than horizontal one. In engineering practices, butterfly-shaped windproof net may be thin to reduce engineering costs, make the net more safe and prolong its service life [5]. Within certain porosity, the butterfly-shaped net may somewhat reduce wind speed and meet the needs of wind prevention and dust emission.

(2) Layout of Windproof Net

In view of horizontal arrangement of windproof net, the net is mainly set up in the predominant wind direction and beside to form an “L”-shaped layout, or the net is arranged in four sides to form

“口”-shaped layout. To make windproof net more protective, several windproof nets would be arranged [6].

(3) Height of Windproof Net

The height of windproof net is mainly represented by the times of stacking height. Through several wind tunnel experiments, the data and the numerical simulation results have suggested that the wind speed may be well reduced once the height of windproof net is 1.1 to 2 times as high as the stacking height. Although the wind speed may be reduced to a greater extent when the height of windproof net is 1.5 to 2 times as high as the stacking height, the efficiency is lower as compared with the height of windproof net as high as 1.1 to 1.5 times of the stacking height. The height of windproof net and the effect for reducing average wind speed are analyzed, as shown in Fig1. The height of windproof net is closely connected with construction difficulty, construction safety and engineering costs, etc, so it has been widely acknowledged within the industry that the height of windproof net shall be generally determined as 1.1 to 1.5 times of the stacking height in designing windproof net.

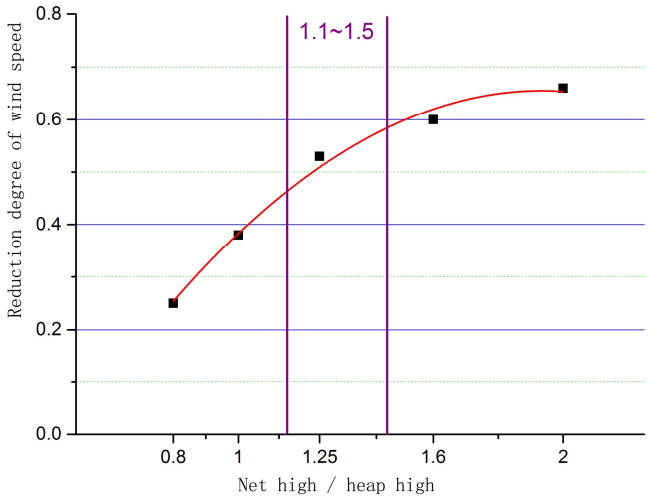

Fig1. Analysis on Height of Windproof Net and Effect for Reducing Average Wind Speed

(4) Porosity of Windproof Net

Porosity refers to the ratio of open meth area to total area, and the research has suggested that the windproof net within certain porosity is more effective for dust suppression [7]. Currently, porosity is mainly selected between 25% and 45%. It will be primarily dependent upon the workmanship of the manufacturers of sheets for windproof net as long as there are no special studies on porosity of windproof net for certain projects, namely physical modeling experiment or numerical simulation.

To examine and analyze the protective distance of windproof nets with different porosity and their effects for reducing wind speed, the Tianjin Research Institute for Water Transport Engineering carried out a physical modeling experiment in its hall of wind tunnel experiment to determine the porosity of windproof net. Modeling experiments were conducted for butterfly-shaped nets with different porosity in six cases, including 41.9%, 34.4%, 30.7%, 28.8%, 25.5% and 0%. The analytical results have suggested that the butterfly-shaped windproof net is more effective for reducing wind speed when the porosity is approximately 30%, as shown in Table 1.

Table1. A Comparison of Average Wind Speed and Effect for Reducing Wind Speed among All Experimental Nets

	0%	25.5%	28.8%	30.7%	34.4%	41.9%
Average Wind Speed	3.28	3.09	2.60	2.65	2.69	3.19
Average Effect for Reducing Wind Speed	0.45	0.48	0.57	0.56	0.55	0.47

By analyzing the experimental data, it is concluded that the windproof net is effective for protecting against wind in front of the net within a distance that approximately equals to twice the net

height and preventing wind behind the net within a distance that is above 28 times of the net height. Fig 2 shows the curve of different porosity of windproof net versus wind speed.

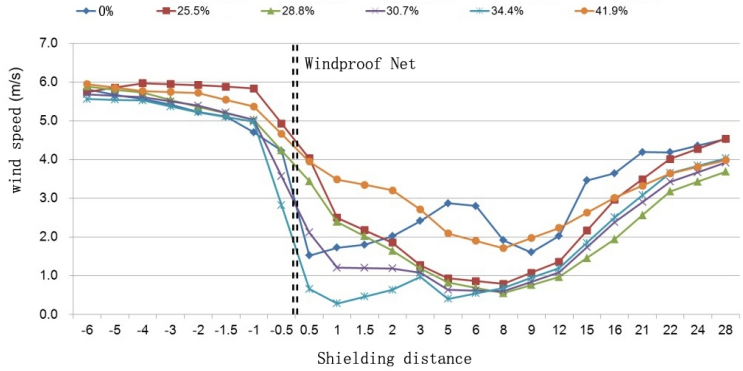

Fig2. A Comparison of Wind Speed for Windproof Net 0.8 Times as High as of Stacking Height

(5) Existing Problems

Taking all of these into consideration, the present researches of windproof net are mainly aimed at the parameters such as the types of board, the height of net and porosity; while little attention is paid to study the types of the plane layout of windproof net. The scheme of plane layout is an important part which affects the investment cost of the windproof net project. The environmental conditions vary from bulk cargo harbors. It decides one scheme of plane layout of windproof net cannot suit for all harbors. Scientific verifications should be conducted according to the environmental conditions of harbors, which will make the designing scheme of windproof net more accurate and efficient, and helps to reach the best balance of both the environmental effects and the investment costs.

Methods for Optimizing Layout

Priority is suggested to be given to designing butterfly-shaped windproof net with square layout, a weight height 1.3 times as high as the stacking height and 30% porosity in determining parameters of windproof net for each project, so as to make sure that a windproof net is effective for suppressing dust. The data about environmental conditions pertinent to this project were collected, including geographical location, meteorological conditions, construction scale, processes, targets of environmental protection and environmental investment of this project. They were sorted out and analyzed to particularly consider meteorological conditions, field layout, size of yard, topographical conditions. Meanwhile, the fundamental design scheme is developed according to different environmental conditions and characteristics. Specifically, it is optimized as follows:

(1) Meteorological Conditions

Ports, especially large ports, are located along coastlines, where the land is flat and wide with high wind speed and distinct seasonal climate. It is not only necessary to consider predominant and secondary wind directions, but also to particularly take the direction of strong wind into account.

① Windproof nets shall be considered to be set up in upper and lower parts of predominant wind directions to prevent wind and suppress dust in areas where the predominant wind directions have been fairly apparent, there have been no directions of strong wind and the annual average wind speed has been lower than the wind speed initiated by cargos over the past years. In order to form an L-shaped arrangement or three-side arrangement in the shape of "⌊⌋". In case of poor effects of dust suppression, the windproof net can be made higher in the upper part of the predominant wind direction, in order to increase the overall efficiency of windproof net for suppressing dust.

② In general, windproof net is arranged in the shape of "口" in areas where the predominant wind directions aren't detectable. It is necessary to consider increasing the height of windproof nets in upper parts of strong wind if there are any strong wind directions in the area of this project, in order to make the windproof net more effective for dust suppression.

(2) Field Conditions for Setting up Windproof Nets

Generally, it is more effective for arranging windproof net along the boundary of a yard because the wind will blow at a lower speed immediately after it passes through the net. However, other buildings that may satisfy the requirements for normal operations of ports usually need to be constructed around a yard, so it is firstly necessary to deeply examine the field environment of a project under contemplation, including machinery, buildings inside and around a yard, roads within plants, railways and underground pipelines, in order to make sure normal operation of the yard, functions or maintenance of accessory buildings won't be impacted by construction, use and later maintenance of windproof net. Efforts shall be made as follows:

① Buildings of a yard like towers for conversion shall be regularly maintained, and windproof net shall be set up with certain space spared for overhauling or maintenance.

② The windproof net will be more effective for dust suppression as long as it is closer to the stack. Nonetheless, large-scale equipment like stackers and reclaimers will be influenced in a yard. As a consequence, the stacking area will be reduced and space shall be appropriately spared.

③ Layouts of facilities such as underground pipelines and drains shall be collected. In designing the floor plan of windproof net, it is necessary to bypass these pipelines.

④ Certain adjustments shall be made on structure of windproof net that crosses railroad or road, so as not to affect normal operation of a port, whereas the overall effect of the windproof net for dust suppression will be impacted. Hence, structural changes to the windproof net shall not be ignored in later physical modeling or numerical simulation.

(3) Size of Yard

Windproof net is somewhat effective for reducing the speed of wind that passes through the net and effective within certain range. According to the wind tunnel experiment for porosity, the windproof net with about 30% porosity is more effective for reducing wind speed within a distance that is approximately twice and 28 times as long as the net height before and behind the net. In case that the stacking height is 12m and the windproof net is 1.3times as high as the stacking height, the net will be effective for protecting against wind within nearly 470m. The height of the windproof net may be increased accordingly to widen the protective distance behind the net if a yard is a little long. In a large or long yard, some stacks in the middle of the yard would not be within the protective range behind the net. In this case, a windproof net shall be additionally set up in the middle of the yard to separate the area and to horizontally arrange the windproof net in the shape of "日".

(4) Topographical Conditions

Some yards are near mountains or hillsides that significantly impact air flow, so windproof nets may not be set up beside a mountain, or the height of windproof beside the mountain net may be appropriately reduced in horizontally arranging windproof net according to geographical location of a project. Windproof net may be horizontally arranged in the shapes of "—", "L" with two sides and "凵" with three sides. In addition, some yards are constructed at different height and gradient due to their topographical conditions. Under this circumstance, the yards at high altitudes are effective for protecting ones at lower altitudes. It is advisable to reduce the height of windproof net at high altitudes to save investment costs.

Taking all of these into consideration, when designing the scheme of plane layout of windproof net, the square scheme can be closed firstly, and then be optimized in turn on the basis of the characteristics of local conditions where the projects located. It can reduce the unnecessary plans. Finally, the scheme is put forward that is accurate and efficient as well as suitable for the characteristics of the project.

Numerical simulation example

Taking a harbor as an example, the method to the parameters of the windproof net is optimized according to the above environmental conditions. Then the scheme of plane layout is optimized for the harbor. Numerical simulation calculations validate the practicality of the above research results.

⑴The basic conditions of the port

The port transport cargo of coal, 17 meters high, according to many years of meteorological observation data, the dominant wind for ENE wind direction, followed by NE wind; annual average wind speed of 4.29 m/s. The port SSW direction has a height of more than 100 meters hill, the length of the south side of the mountain and the site is quite, the relative position of the port and the mountain is shown in figure 3.

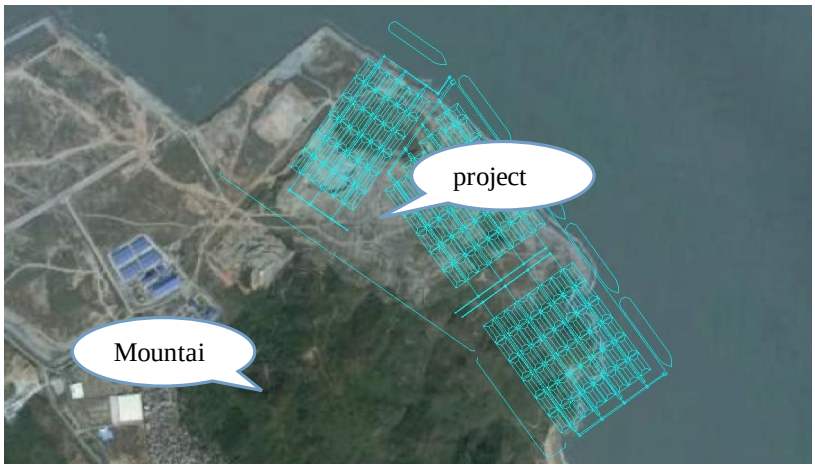

Fig. 3 relative position of port and mountain

⑵ Layout of Windproof

The result can be concluded by this analysis on the basis of both the environmental conditions and the optimal method. It is that the prevailing wind of this region is ENE wind. The mountain is located in the downwind direction of the prevailing wind, and the height of mountain is over 100m, which plays a better role of dust prevention and prevent the diffusion of dust, and protection the villages behind the mountain. Therefore, the scheme of this project considers on the basis of the common square scheme that the windproof net should not be built in south of the yard which guarantees the dustproof effect and saves the environmental cost for more than millions. In order to show the dustproof effect of the mountain and the practicality of the method, there are two schemes of plane layout of windproof net are put forward which conduct numerical simulation calculations using the aerodynamic modeling and compare the two results of schemes. The first scheme shapes as“⊔”while the second “口”. The height of windproof is 21m. The specific plane layout of windproof is illustrated in Figure 4.

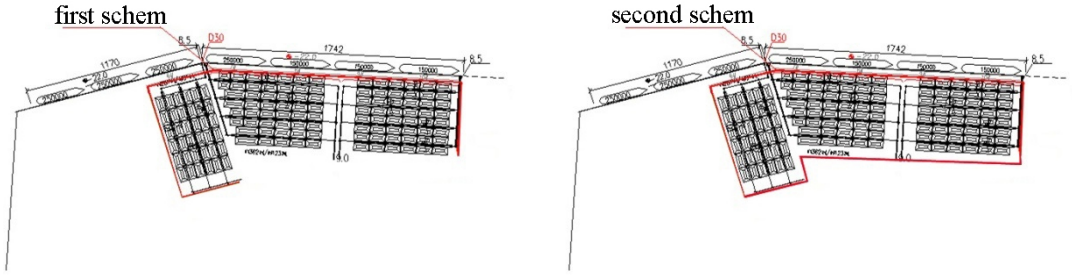

Fig 4 Schematic diagram of the plan of wind net plane layout

⑶ Air dynamic model calculation

①Calculation model

The calculation area is the positive 16 boundary type prism, the prism height 200m, the bottom surface radius 6000m, the height of the stack is 17m. Center of the calculation area. Figure 5 for the calculation model diagram (global).

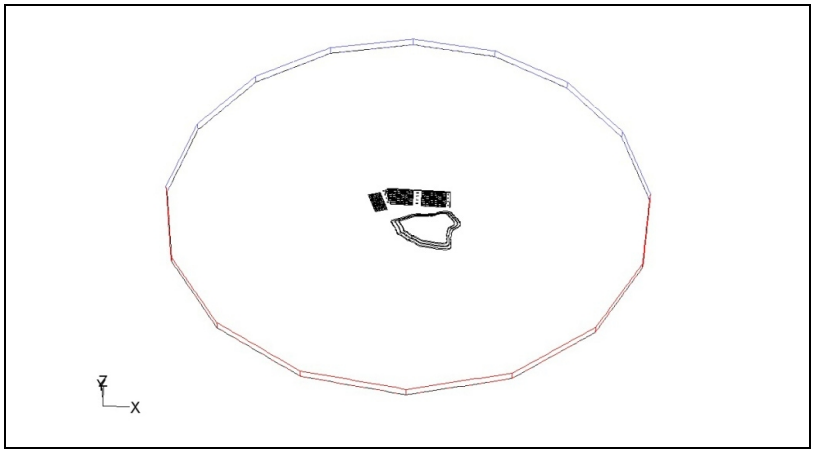

Fig. 5 calculation model (global)

②Mesh generation

The calculation area is divided into 24 grid regions. Each region is divided into grids, and the total number of the project is 13 million. Fig. 6 distribution of grid structure and stacking of yard.

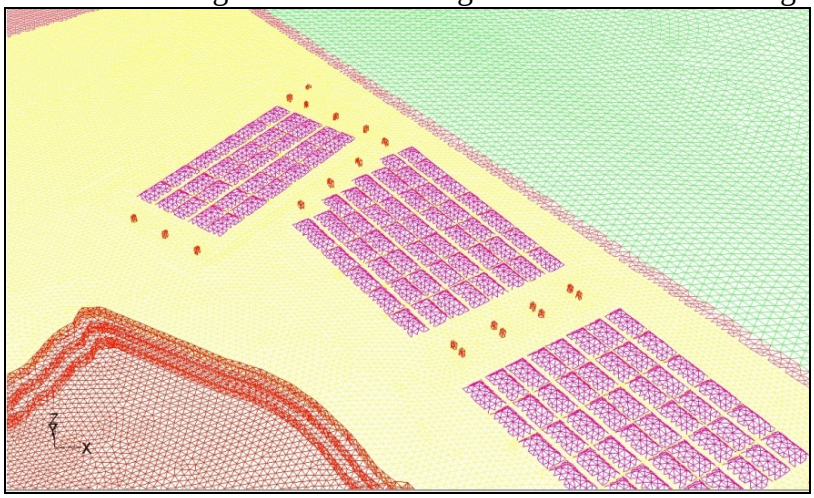

Fig. 6 the distribution map of the building and the surrounding of the stack (local)

③Calculation result

Taking the dominant wind direction of ENE as an example, the change of wind speed and flow field in the yard was observed. See figure 7.

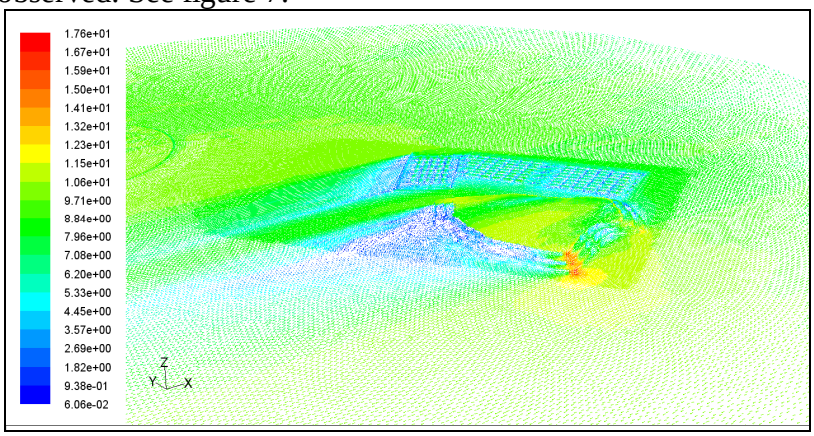

Fig. 7 scheme of a ENE wind direction and wind speed flow field map

Generally speaking, in natural dry conditions, the moisture content of coal surface is about 3.2%, and it tends to dust. According to The Design Standards of Environmental Protection of Harbor Projects,（JTS149-1-2007）[8] and the national related environmental requirements, the moisture content of coal surface in yard should keep at about 6%~10%. It calculates at 8%, and the results of the rate of dust proof are shown in table 2.

Table 2 Comparison of the dust suppression ratio of the sand control scheme

Layout scheme	Comprehensive dust suppression ratio (water content 8%)
Option one	84.68%
Option two	86.27%

From this, after building the windproof net in south of yard, and under the condition of 8% moisture content, the rate of dust proof rises from 84.68% to 86.27%, only increasing 1.59%. The result shows that the mountain in south-west of yard plays certain role of proofing wind and dust. It can save the environmental cost for the harbor for more than millions instead of carrying out the unnecessary scheme shaped as"口". By the example of the digital analogy, it is feasible for the scheme of plane layout of windproof net that analyzes of harbor environmental conditions and optimizes the scheme.

Conclusions

This essay comes up with the method to optimize the scheme of plane layout of windproof net in turn according to the conclusion and the analysis of local environmental conditions of each project site which includes the conditions of weather, field nets and terrain as well as the scale of yards. The method will be verified through numerical simulation calculations. It can reduce the unnecessary plans. Finally, the scheme is put forward that is accurate and efficient as well as suitable for the characteristics of the project.

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