# Development and Application on Silo Storage in Coal Terminals

Panpan Zhang

[1] China Waterborne Transport Research Institute, Beijing, 100088, China

[2]Key Laboratory of Logistics Equipment & Control Engineering, Beijing, 100088, China

peterpan9152@126.com

## Abstract

With the developments of technique and enhancement of public environmental awareness, ports around the world focus on research of environment-friendly and energy-saving storage technology. Silo storage is now becoming more and more important in port terminals, especially in coal terminal. In this paper, technological developments for silo storage in coal terminal were introduced. Applications of silo storage for coal are summarized. And research trends are analyzed according to the silo storage situation.

## Keywords

Port terminal, Bulk cargo, Coal, Silo storage.

## 1. Introduction

With the developments of technique and enhancement of public environmental awareness, silo storage for coal is becoming popular in the port terminal. In 2003, Enviroment Management System in Port of Los Angeles was equipped to improve the air quality. And San Pedro Bay Ports Clean Air Action Plan were carried out by Port of Los Angeles and Port of Longbeach. In Europe, ports were united to undertake the Eco-Ports program. In Holland, Rj jnmond Regional Air Quality Action Program was started in Roterdam Port and Development of Clean Port Guideline for 2020 was drafted. In 2015, Special Control Program for Ships & Ports in China was issued to improve the air quality of port areas. Among those programs mentioned above, pollution control in coal terminal is serious. Measures must be taken to minimize the coal dust and silo storage is a good way.

In paper, technological developments for silo storage in coal terminal were introduced. Applications of silo storage for coal are summarized. And according to the application of silo storage, research trends of silo storage technology in future are analyzed.

## 2. Theoretical Study in Silo Storage

In silo storage area, granular mechanics is fundamental. Because of the complexity of bulk cargo, the theoretical analysis and experimental study[1-5] is still a research focus.


Fig. 1 Material property testing in the Jenike&Johanson lab

Jenike & Johanson established a lab to study the material properties (shown in Fig. 1). Based on the material properties such as water content, angle of repose, dynamic accumulation angle, internal friction coefficient and external friction coefficient, virtual design was applied in the product development. Experiments are carried out as well. So far, over 1000 kinds of materials including powder and bulk-solid material were tested in the lab.

In order to study the silo storage, a silo was built in japan. The capacity of the silo was 360 $m^3$ and a W-shape cone hopper was applied under the silo which was helpful for the coal blanking, rotary scraper arrangement and rotary working platform buildup shown in Fig. 2.

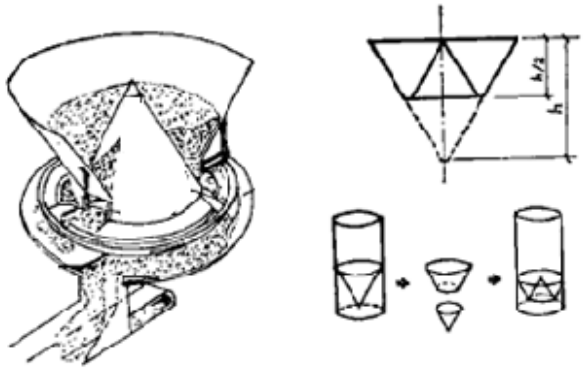

Fig. 2 The W-shape silo experiment system

In the application study, DSH systems developed a kind of dust suppression system which could greatly solve the dust problem in the unloading process for the bulk cargo. The effect of the system is shown in Fig. 3. There is no extra drive for the system.

The theoretical analyses are put into practice and could provide introduction for the terminal operation. The particulate Discrete Elemnet Method (DEM) has become a powerful method in analysizing behaviors of granular materials. However, many researchers used to do DEM simulatioins utilizing different models without experimenta validation, only a small number of studies contributed their predicted results in comparison with laboratial ones with a full set of specified parameters.

Among the various models, the model based on classical contact mechanics between two spheres in undoubtedly reasonable, but until today, there has not any experimental results to prove such mechanics.

Li Yanjie and Xu Yong[6] conducted a comprehensive study on particle piling with sphere elements utilizing the contact-mechanics model, mainly for the non-adhesive dry particles. Numerical and experimental manners were adopted to investigate the behavior of particles shown in Fig. 4.

Fig. 3 The dust suppression system

Fig. 4 silo unloading flow test of steel balls

## 3. Applications of Silos in Coal Terminals

In Rotterdam Port shown in Fig. 5, silos with large diameter are built for coal blending. Belt conveyors were used for coal delivery from the coal silos to the power plants. By using the silos, coal dust greatly decreased.

(1) Hartelhaven (2) Amazonhaven

Fig. 5 Coal silo storage system in Rotterdam Port

In Japan, coal silos were also built in the power plant shown in Fig. 6. The silo is 37 meters in diameter and 48.5 meters high with capacity of 31000 tons. Because building foundation is greatly affected by the height of silos, large diameter silos were widely applied around the world. The unloading capacity is 1600 tons per hour.

Fig. 6 The silo storage system in Japan

In China, first silo storage system for coal were built in 2008.the system consists of six silos shown in Fig.7 with diameter of 20 meters and with height of 43.2 meters[7,8]. In this silo storage system, the Extromat Rotary scraper discharger was chosen to unload the cargo, the efficiency of which is 1600 tons per hour .The capacity of each silo is 8000 tons. And in 2012, 24 silos were built in Huanghua Port and the capacity of each silo is 30000 tons[9-11].

Fig. 7 Coal silo storage system in China

The common characteristics of the silo storage application mentioned above are as follows:

1) Short storage time is necessary. In Huanghua Port, the average storage of coal is 3 days which helps to reduce the spontaneous combustion of coal.

2) The silo storage system is connected to the open storage area in case of emergency.

3) Coal agglomeration happens in silos, so only 5-6 kinds of coal can be stored in silos.

4) Silo storage systems require better logistics scheduling and safety monitoring system compared to open storage.

## 4. Conclusion

In this paper, technological developments for silo storage in coal terminal were introduced. Applications of silo storage for coal are summarized.

Although the silo storage system was applied in several ports, there are still a lot to study in future. In the following paragraph, several aspects of silo storage research need to be strengthened

1) Material properties are fundamental in the bulk cargo area. The handling technologies including storage mode, loading and unloading equipment are based on material properties.

2) Virtual simulation combined with experimental study is an efficient and economical method for the design of equipment design, especially in the large silo storage system setup.

3) Dust control and explosion protection is still crucial in the bulk cargo handling process. Effective dust control equipment research and development is still necessary.

4) last but not the least, 3D technology will facilitate the silo storage system. It can provide a direct and vivid picture for the system, which will be helpful for the operators.

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