APAD Technology™

Construction and renovation construction to improve dust control in the interest of energy economy and occupational and environmental safety

Summary

Creating and maintaining negative pressure is an absolute requirement to implement occupational and environmental safe dust control on construction sites. Controlling the negative air pressure level and simultaneously constantly filtrating the required amount of air is often either very difficult or even impossible. In addition this often also causes significant energy loss in the form of heat loss during cold season.

New innovation, APAD Technology™, significantly improves occupational and environmental safety of dust control on construction sites simultaneously minimizing the heat loss caused by dust control.

1. Introduction

Conducting dust control on a construction site often gives gray hair and is seen only as an extra cost. The reason for this is in part lack of information but also attitudes. However a fact is that to implement dust control following current instructions and regulations one simply has not had the technology and equipment allowing for occupational and environmental safe reliable and functional dust control. Using new APAD Technology™ allows for both sufficient air filtration as well as negative pressure control while simultaneously reducing the need for heat energy.

2. The need and challenges of dust control

The construction sector employs tens of thousands of people that are somehow exposed to different types of dust on daily basis. People already know how to protect themselves against asbestos and microbes, and awareness of their side effects are known. Many other, impossible to visually detect dust types are however particularly harmful to the construction workers and to the persons in the environmental impact affected area of the construction site. Notably various stone dusts include e.g. quartz, which is particularly harmful to human health. Quartz occurs not only in different rock types but also in other building materials that contain natural sand as base material. These include, for example, mortar, lightweight concrete, concrete and bricks. Various fillers are also comparable to mortar. Therefore, prevention of harmful dusts on construction sites is of utmost importance in terms of environmental safety and the safety of workers [1].

In Finland, the safety of construction workers is taken into account in the legislation. Occupational Safety and Health Act obliges the employer to ensure employees' working conditions and safety at work [2]. The Government Decree 205/2009 (Finland) emphasizes the working conditions of construction work, and states that "in order to prevent risks posed by chemical agents and in dust prevention one must use sufficient exhaust equipment. If necessary, the working spaces shall be compartmented and a ventilation system and equipment allowing for pressure difference implementation must be used. In case local exhaust devices are used, they must be kept in working order.

Devices shall operate in such a way that the health and safety of 15 employees is not endangered at any time. In case necessary for the safety and health of workers, local exhaust equipment must be equipped with a monitoring system that detects and notifies malfunctions" [3].

2.1 Dust control methods on construction sites

Traditional methods of dust control include using a working method causing as little dust as possible, compartmentation and protection of working spaces, using local exhaust equipment with dust creating equipment and using micro filter equipped negative air pressure equipment for depressurization and for air cleaning.

2.2 Traditional way of depressurization on construction sites

The guideline for calculating the need of negative air pressure equipment for dust control is that air should be filtered 6 to 10 times per hour [4, 5]. This is not very difficult to accomplish if one wants to carefully implement the dust control of a construction site. When measuring the negative air pressure the recommended multiplier is ten (10) to accomplish the minumum level (6) even when the filters of the negative air pressure equipment get dirty and therefore clogged. Then the calculatory air filtration of a 1000 m^3 workspace should be 10 x 1000 m^3 = 10 000 m^3/h. Depending on the air filtration capacity of the chosen negative air pressure equipment one should place the needed amount of equipment to the space to accomplish the required calculatory air filtration level. Correctly measured air filtration decreases the hazardous particle concentration of the air in the workspace which signifactly improves work safety.
The guideline for the negative air pressure level is respectively set at -5 to -15 Pa [5]. The purpose of the negative air pressure level is to make sure that no harmful particles or impurities get spread outside the workspace. A -5 Pa negative pressure is still fairly low and therefore sensitive to any changes in conditions affecting the air pressure difference e.g. wind factor [4]. Depressurization of a workspace is conducted by directing the micro filtered air of the negative air pressure equipment outside the workspace and by simultaneously bringing less compensation air to the workspace.

2.3 The challenges of the traditional way of depressurization on construction site

Creating and maintaining a stabilized negative air pressure level on construction sites in a traditional way i.e. by utilizing compensation air is without new technology one of the most difficult challenges of dust control. The loss of negative air pressure or not having it to begin with is a significant occupational and environmental safety risk which also causes unnecessary cleaning costs.

2.3.1 Leaky workspaces and workspace compartments

The spaces to be depressurized may often be very leaky which prevents the creation of negative air pressure or enables creation of only a very weak negative air pressure level. Traditional negative air pressure equipment does not indicate the negative air pressure level and in case no air pressure difference measuring devices are used, the real air pressure level is unknown. Most of the traditional negative air pressure equipment do not give any alarm in case of loss of air pressure difference.

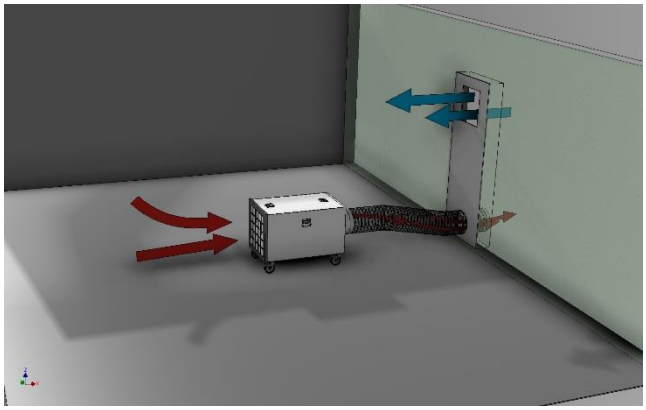
2.3.2 Changes in negative air pressure level and dirtying filters

On construction sites dust leakages are often caused by human errors or technical issues affecting the negative air pressure level such as nearby elevator movement or changes in the operation of the building's ventilation machinery. Typical human errors include door openings or leaving doors open, breakages in workspace compartments and other such factors that radically affect the increase of the amount of compensation air. When targeting at 10 Pa negative air pressure level by using a traditional negative air pressure equipment, compensation air is directed to the workspace through an opening the size of which is required to reach the desired level of negative air pressure. Additionally some amount of compensation air will often leak into the workspace uncontrolled through the structures of the building. The negative air pressure level reached immediately after installation will most likely remain at least temporarily but as dust starts to collect to the filters of the negative air pressure equipment the air volume of the equipment decreases causing the air pressure to increase respectively (e.g. from -10 Pa to only -5 Pa). In the worst case a significant dirtying of filters will cause the complete loss of negative air pressure as the compensation air opening will not change.
Technically it would be possible to monitor the negative air pressure level and on the working site personnel could compensate the reduced air volume due to clogged filters by increasing the amount of compensation air. However in practice this would be impossible to implement. Therefore, as traditional negative air pressure equipment discharges air with certain rpm and compensation air is directed to the space through a standard size opening the equipment will not react to changes in the pressure difference due to door openings, elevator movement or changes in the operation of ventilation machinery.

2.3.3 Heat loss of traditional depressurization during cold season

The way a traditional negative air pressure equipment works is that the outlet air of the equipment is discharged outside the workspace and the amount of compensation air needed to reach the desired level of negative air pressure e.g. -10 Pa is directed into the space. What this means is that all the air volume of the equipment is discharged entirely outside the workspace. The compensation air will come either directly or indirectly from outside which during cold season will cool down the building. For larger workspaces mainly high air volume appr. 4000 m³/h negative air pressure equipment is used, sometimes several equipment simultaneously, as the amount of equipment is calculated using the air volume calculation in section 2.2. The air volume of the negative air pressure equipment can not be decreased by lowering the rpm either as that would significantly reduce the air filtration capacity. In turn decreasing the amount of compensation air would increase the negative air pressure (e.g. from -10 Pa to -20Pa).

Because of the need for larger volumes of compensation air for high volume negative air pressure equipment an unnecessary large amount of heated air is discharged when using traditional negative air pressure equipment. For instance in case of temporary heating of construction sites, the need for heat is calculated using a formula of appr. 10 – 20 W/m³ [6]. In case the amount of discharge air could be reduced to 50% without reducing the filtered air volume still reaching the desired negative air pressure level, significant cost savings would be gained due to minimizing the heat loss.



Picture 1. A traditional negative air pressure equipment with large compensation air volume

3. APAD Technology™ – the new era of dust control safety and energy efficiency

As a result of a Finnish innovation a new equipment technology has been developed to significantly improve the occupational and environmental safety of construction sites and to bring significant cost savings due to decreased volume of discharge air. At the same time the equipment works as an educational tool for operators as it already at installation phase indicates whether the workspace is air tight enough to reach the desired level of negative air pressure.

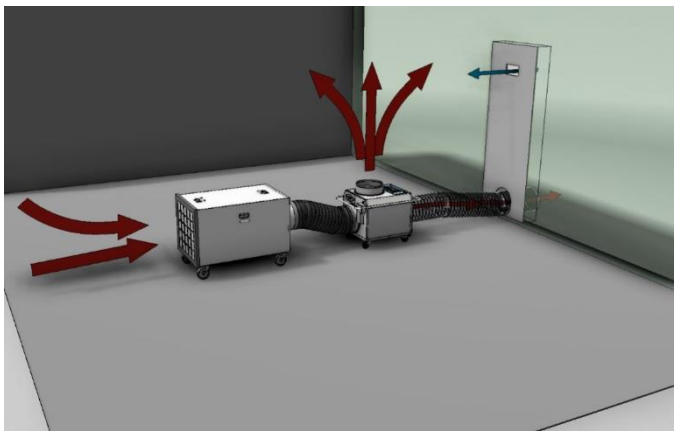
3.1 APAD Technology™ – method of operation

APAD – Active Pressure Adjusting Device – is a new Finnish innovation that has been developed and patented since year 2013. APAD can be used with almost all brands of negative air pressure equipment. The APAD is connected to the negative air pressure equipment with an air hose. The air of the negative air pressure equipment is directed via hose to the APAD and from the APAD either back to the workspace or outside the workspace or the whole building. The main components of APAD include a pressure difference meter, control unit, air division compartment, damper motor and dampers.

The pressure difference meter is set to measure the pressure between the spaces that the pressure difference is required. The pressure difference meter can therefore be set to measure the pressure difference between e.g. the workspace and outside or the workspace and the surrounding working area depending on the need of each construction site.

The information of the pressure difference meter then goes to the control unit that respectively controls the operation of the damper motor and dampers. The filtered air coming from the negative air pressure equipment is divided into discharge air and recycled air that is returned to the workspace. The equipment

removes only the amount of air from the workspace that is needed to reach and maintain the desired level of negative air pressure. The desired air pressure is set using the digital display of the unit.
The amount of discharge air is always in relation to the tightness of the space, but now using APAD Technology™, the amount of compensation air can be significantly reduced as the equipment adjusts to each prevailing condition and changes the discharge air – return air ratio according to the changes in the pressure difference. The equipment also includes an alarm and light signal in case of negative air pressure decrease or loss.



Picture 2. APAD depressurization system significantly reduces the need for compensation air.

3.2 APAD Technology™ – benefits

APAD improves both occupational and environmental safety of construction sites working simultaneously as an educational tool for air tight compartmentation construction.

3.2.1 Accurate adjustment and monitoring of pressure difference

APAD Technology™ is based on active pressure difference measurement that controls the negative air pressure level of the workspace. The equipment removes only the amount of air from the workspace that is needed to reach and maintain the level of negative air pressure without limiting the amount of filtered air. In case of dirty or clogged filters or compartment breakages APAD system detects in real time any change in the pressure difference and reacts immediately by controlling the damper motor and dampers adjusting the discharge air – return air ratio accordingly. In the future it is possible to use APAD Technology™ as a pressure difference surveillance system that alerts using the built-in alarm system in case of loss of pressure difference due to e.g. door opening etc.

Picture 3. The pressure difference can be set with 1 Pa accuracy using the display of the control unit

3.2.2 Optimal negative air pressure level for each need

APAD does not produce oversized negative pressure to the space and it can be operated in spaces of different size and shape. Requirement is that the volume of discharge air of the negative air pressure equipment and the tightness of the workspace are sufficient enough to enable reaching the desired level of negative air pressure. In case any of these are not sufficient enough the system may not be able to create the desired level of negative air pressure.

In practice APAD Technology™ enables radical oversizing of depressurization. One can place a very powerful negative air pressure unit into a fairly small space without having excess negative air pressure due to recirculation of air. In case of a larger workspace with several negative air pressure units in operation all units can be used for discharging of air as APAD Technology™ will in any case only discharge the required amount of air to reach the desired level of negative air pressure. Thus one has extra power resources in case of single unit breakdown or broken compartment wall or door openings to compensate the caused pressure difference which significantly improves occupational and environmental safety. It is recommended to use APAD Technology™ in combination with all negative air pressure equipment discharging air outside the workspace. In case the negative air pressure equipment is used only for air filtration purposes inside the workspace using APAD Technology™ is not needed.

3.2.3 Less compensation air and improved energy efficiency

APAD Technology™ equipment works optimally in different conditions with changing amount of compensation air in different workspaces and even in a single workspace during different work phases. Traditionally the size of the compensation air opening has been fairly large to avoid excess negative air pressure. As a result, unnecessary large amount of warm air has been discharged which causes significant heat energy loss. APAD Technology™ based system requires significantly less compensation air still reaching the desired negative air pressure level. This way the amount of discharge air is significantly reduced the same as the amount of possible cold compensation air resulting in an energy efficiency above any previously known technology of depressurization. APAD Technology™ will return even 50 to 70% of the filtered warm air back to the workspace without losing the heat energy contained in that air [7]. And as the amount of compensation air reduces the efficiency ratio of the temporary heating system of the construction site is also better which results in direct cost savings on heating costs.

3.2.4 APAD Technology™ as an educational tool

On construction sites the making of compartmentations and the tightness of workspaces are often on a fairly poor level. This is mainly due to lack of equipment to properly conduct and verify the tightness of workspaces and compartmentations. The installations have relied on placing the required amount of negative air pressure equipment to the workspace to reach the required, or at least some kind of level of negative air pressure. In most cases this may work but in reality the prevailing air pressure level is often unknown. The level of negative air pressure may be very weak e.g. only -3 Pa and at times it may be lost completely. This problem often presents itself in the case of hazardous material demolition work where the same working methods have been in use for years despite of several cases of very expensive cleanings due to dust leakages.

APAD Technology™ is ruthless as it does not forgive negligent implementation of compartmentations. The system will alert until the tightness of the workspace and the capacity of the negative air pressure equipment match the desired level of negative air pressure and the system is able to produce and maintain a controlled negative air pressure.

Picture 4. APAD Technology™ air pressure adjusting device

3.3 Case – using APAD Technology™ in a school indoor air quality renovation project

The test phase of APAD Technology™ included a series of so called field tests where the APAD devices were used in combination with the negative air pressure equipment already installed at the construction sites. One of such sites was a school building situated in Pori, Finland. The construction project included indoor air quality related work with hazardous material demolition, encapsulation and rebuilding work during the summer of 2015.

The project is a good example of how APAD Technology™ teaches how to implement air tight compartmentation. During the start of the project the windows had been removed and replaced with plywood and acrylic sheeting for generating light into the workspace. The plywood and acrylic sheets were mounted using mainly screws. The workspace was equipped with two (2) 4000 m³/h negative air pressure units that by calculation were sufficient to fulfill the air filtration requirement.

Traditionally this is when the actual renovation work would have started. However, after installing two (2) units of APAD devices one discovered that the system was not able to create any level of negative air pressure. In other words, the APAD devices discharged 100% of the air coming from the negative air pressure units but still the alarm system alerted insufficient negative air pressure. The negative air pressure level measured by the APAD device was appr. 0 … -1 Pa. Based on this information one could conclude that the amount of compensation air flowing uncontrolled to the space was so large that the capacity of the negative air equipment was not sufficient, even when calculated correctly, for creating the required level of negative air pressure. One could also notice that the installations of the plywood and acrylic window shields were so loose that large amounts of air got into the workspace. Therefore a simple foam rubber gasket was added to the window shields and a few air inlets were sealed. After this the condition changed completely and the set -9 Pa negative air pressure was reached easily. In addition some 50% of the filtered air was now being returned to the workspace by the APAD.

During the test phase one also discovered that setting a negative air pressure of -5 Pa resulted easily in a fairly fast complete loss of air pressure in case of door openings whereas using a negative air pressure of -10 Pa does not cause as rapid loss of pressure difference.

Overall, the introduction of APAD Technology™ to the project was considered very valuable by all involved in the process, both the client and the contractor, and the equipment saved the other parts of the building from damages caused by dust leakages. The accuracy of the alarm system and fast response to pressure variance caused by human errors received special thanks from both the constructor and the client.

In case the project had been carried out during a cold season remarkable cost savings would have been gained as well due to fairly large amount of recycled air [8].

Picture 5. Control unit display and a photograph from the Pori school project.

4. Summary

Conducting depressurization of construction sites using APAD Technology™ will generate significant occupational and energy efficiency improvements and cost savings due to reduced need for heat energy. The amount of recycled air using properly implemented compartmentations is as high as 50 to 70% that, using a traditional technology, would have been discharged outside the building.
APAD Technology™ maintains and verifies the desired negative air pressure level that until now has been in most cases practically unknown.

List of references

[1] Lappalainen J., Oksa P., Mattila M., Kivi P. 1997. How to determine the construction work related health risks. Work place survey methods and usage. Institute of Occupational Health. Hakapaino Oy, Helsinki.

[2] Institute of Occupational Health 738/2002

[3] Government Decree 205/2009

[4] Kokkonen A., Linnainmaa M., Koski H., Kanerva T., Laamanen J., Lappalainen V., Merivirta M., Oksa P., Piirainen J., Rautiala S., Säämänen A., Pasanen P. 2013 Renovation construction dust control. Clean and safe renovation. University of Eastern Finland Faculty of Science and Forestry Department of Environmental Science, Kuopio

[5] Koski H., Pasanen P., Linnainmaa M., 2013, PUTUSA –research project – Instruction on renovation dust control, VTT Technical Research Centre of Finland Ltd.

[6] Anttila P., Polartherm Oy, personal interview, Oct 4th, 2015

[7] Nyman M. 2015, APAD pressure adjustment system performance data, test report VTT-S-01821-15, VTT Expert Services Oy.

[8] Seppä T., Rakennustekniikka Seppä Oy, personal interview, July 31st, 2015