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Dial Down Dust and Noise Exposure

Open-structure designs may lower worker exposure levels in aggregate operations.

Many different types of structures and materials have been used to build mineral processing facilities throughout the years. Although structure type and building material were not viewed as significant factors affecting the health of employees in these facilities when they were built, the National Institute for Occupational Safety and Health (NIOSH) has found that building type can impact respirable dust and noise levels. NIOSH performed a study in which it evaluated three building types: masonry, an open-structure design, and a steel-sided design. This study indicated that an open-structure design (no walls) was superior from both a dust and noise (health) standpoint when compared to the other two structure types. Therefore, companies may want to consider this design when building new structures.

Goals and testing

Workers at mineral processing facilities may be exposed to high levels of respirable dust and noise, and NIOSH is constantly developing new techniques to lower these exposures. The vast majority of NIOSH's research throughout the years has been directed at source control techniques for a particular job function or work application. Although numerous techniques have been developed and shown to be effective, there has been very little technology developed to lower exposures to multiple workers throughout an entire structure.

One such study aimed at this more global approach was the total mill ventilation system (Cecala, A.B.; Klinowski, G.W.; and Thimons, E.D. *Reducing Respirable Dust Concentrations at Mineral Processing Facilities Using Total Mill Ventilation Systems.* Bureau of Mines RI 9469). This system was shown to be effective at lowering respirable dust concentrations throughout an entire structure, thus impacting all the workers within the facility. A total mill ventilation system consists of a number of exhaust fans placed on the roof or high exterior walls of a structure to induce a ventilation flow pattern up through the building. Respirable dust reductions ranging from 40 to 65 percent were recorded in a number of field studies evaluating this system.

The structural design study provided the impetus for examining more global techniques that could improve the health of numerous workers within a facility. The intent of this effort was to determine the potential impact of dust and noise levels when comparing three different types of buildings used in mineral processing operations.

A test plan was established to provide a valid comparison of respirable dust and noise levels at the three different types of structures evaluated in this study: masonry, an open-structure design, and a steel-sided design. Respirable dust measurements were taken at numerous locations at all three facilities using both instantaneous and gravimetric dust samplers. Noise measurements were taken to determine the spatial distribution of sound levels in the structures. To minimize background noise, plant operations were suspended while acoustical tests were conducted. Tests to measure the acoustic environment were performed using an external sound source with a known sound power level. A significant factor affecting respirable dust and noise levels in these facilities was the production rates, and thus production levels were closely tracked at all three facilities during this study.

Structures evaluated

All of the structures evaluated in this study were processing silica sand material. Structures 1, 2, and 3 were masonry, open, and steel-sided structures, respectively. All three structures were involved with product sizing; with structures 1 and 2 using the screening technique and structure 3 using the air separation technique. Acoustical evaluations were only performed in the first two structures since personnel and budgetary restrictions did not allow for testing at the third facility. A brief description of all three structures follows.

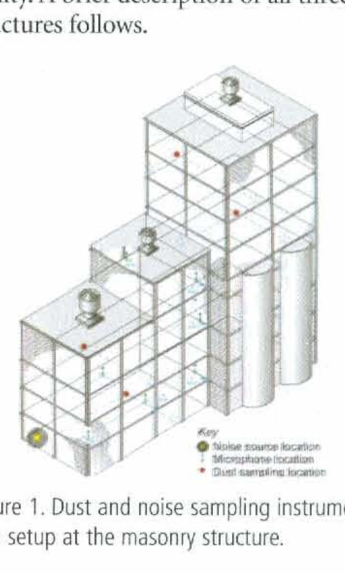


Figure 1. Dust and noise sampling instrumentation setup at the masonry structure.

Structure 1: Masonry. This structure was a nine-story building with steel framing and a masonry block construction. It was a three-tier design with a depth of 32 feet for the entire structure. The first tier was approximately 50 feet high and 33 feet wide, the second was 63 feet high and 25 feet wide, and the third tier was 108 feet high and 42 feet wide. This third tier sat on 50-foot-high product storage silos for bulk loading, making the actual inside height of the building 58 feet. The volumetric capacity of the structure was calculated to be 204,000 cubic feet. Figure 1 provides an overview of the structure with the sample locations for both dust and noise measurements.

Structure 2: Open. The open structure was a four-story steel beam framework with no walls (interior or exterior). Figure 2 shows a monitor being inspected by a researcher at this open-structure facility during testing. This structure was 46 feet long, 22 feet wide, and approximately 75 feet high. Dust and noise sampling locations were at similar positions to those used in the masonry testing. It should be noted that the dust and noise tests were performed at different times because of scheduling conflicts between the various researchers.

Figure 2. Open-structure design used in test.

Structure 3: Steel-sided. The steel-sided structure evaluated in this study was a five-story building. Unlike in structures 1 and 2, both product crushing and sizing were performed in the same building. This structure was 130 feet long, 65 feet wide, and 25 feet high. A 15- by 15- foot tower extended up out of the center of the structure an additional 22 feet. The volumetric capacity of this building was calculated to be 238,000 cubic feet. Figure 3 shows the dust sampling locations at this facility. Again, no acoustical evaluations were performed for this structure due to budgetary constraints.

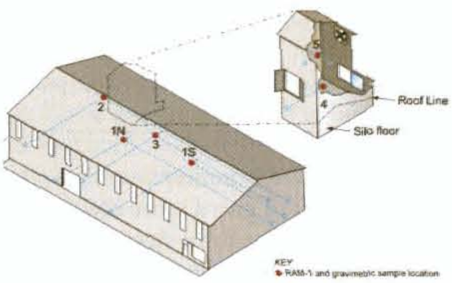


Figure 3. Dust and noise sampling at the steel-sided structure.

Results

Table 1 provides a comparison of these three structures based upon the average respirable dust levels measured with both the instantaneous and gravimetric dust sampling instrumentation during four days of testing. The instantaneous measurements were based upon around-the-clock testing to minimize some of the shift fluctuations and variations natural to a dynamic environment, whereas the gravimetric results were single-shift measurements.

With any closed-wall structure, normally there is an increase in dust levels as one moves up through the structure. This was the case for structures 1 and 3, with dust levels generally increasing at each level. This occurs because the mechanical ventilation pulls the dust up through the building, aided by the natural ventilation of heat generated from equipment and work processes induc-

Table 1.

Structure 1: Masonry		
Sample Location	RAM-1 Monitor Dust Concentration (mg/cubic metric)	Gravimetric Dust Concentration (mg/cubic metric)
First Floor	0.06	0.02
Third Floor	0.10	0.04
Fifth Floor	0.23	0.16
Seventh Floor	0.42	0.29
Ground Floor	0.06	-
Structure 2: Open Structure		
First Floor – North	0.06	0.02
First Floor – South	0.07	-
Second Floor – North	0.03	0.03
Second Floor – South	0.07	-
Third Floor	0.08	0.06
Third Floor – ½ Floor	0.05	0.04
First Floor – North	0.35	0.24
Structure 3: Steel-Sided		
First Floor – South	0.45	0.37
Second Floor	1.01	0.40
Third Floor	2.22	1.81
Fourth Floor	3.61	1.78
Fifth Floor	2.12	1.57

Comparison of average respirable dust concentrations for the three product sizing structures.

One significant benefit from the open-structure design was that there was no dust gradient as one moved up through the floors.

ing a convecting upward flow.

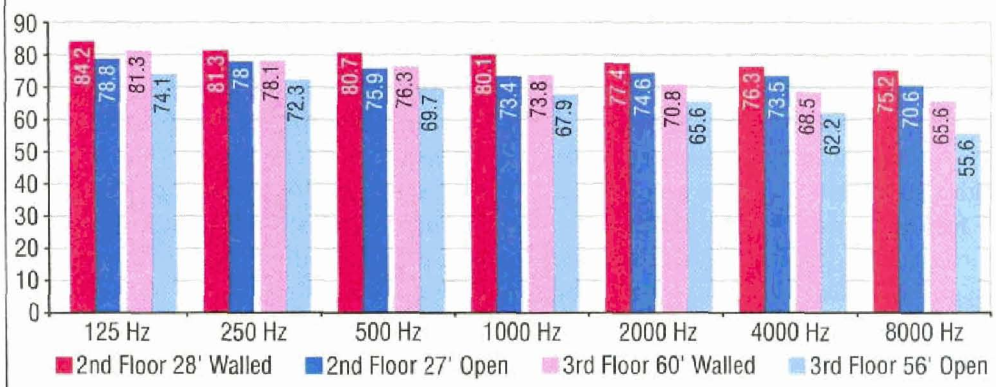
The one exception to this dust increase was at the fifth-floor sampling location for structure 3, as seen in the breakout drawing in Figure 3. A fan located at the top of the structure pulled a good portion of the supply air from the open door on the opposite side of the tower at the fourth floor. As the air came in from outside and swept across the tower to the fan, it traveled across the fifth-floor dust sampling location. Although this had a positive impact on lowering dust levels at the fifth-floor sample location, this is not an effective ventilation flow pattern for the entire structure. Dust levels below this fifth-floor location were not well ventilated, which caused respirable dust concentrations in this area to be elevated.

One significant benefit from the open-structure design in structure 2 was that there was no dust gradient as one moved up through the different floors. Instead, dust levels varied slightly from floor to floor at this open structure with no consistent pattern. In addition, respirable dust levels were extremely low as compared to levels measured at the other two structures. It should be noted that no visible dust plume was ever observed flowing from this open structure during the entire evaluation period. The minimal amount of dust that was not contained by the primary dust control systems at this operation migrated from the structure based upon the prevailing wind direction and speed. This dust was quickly diluted to undetectable levels within a close proximity to the structure and should have no impact on other plant personnel, nearby communities, or the environment.

In an effort to give a more accurate comparison of the three structures, a normalized dust concentration was calculated for each operation based on production levels. Table 2 provides the dust concentration based upon an equivalent production rate for each facility. The results from these normalized calculations further indicate how effective the open-structure design was at minimizing respirable dust levels. This comparison shows that, when normalized for equivalent production levels, respirable dust levels at structures 1 and 3 were 4.3 and 1,379 times higher than respirable dust levels measured at structure 2, respectively.

The noise testing results are from the octave-band sound pressure level (SPL) measurements taken at the masonry and open-structure sites. The sound pressure levels are based upon the distance and sample location relative to the noise source located on the ground floor. Figure 4 provides an overview of these results. This graph shows two representative sampling locations in structures 1 and 2. The first location was one floor above the noise source, 28 feet away in the masonry structure and 27 feet away in the open structure. The second location for both structures was two floors above the noise source (third floor) and approximately 60 feet and 56 feet away, for the masonry and open structure, respectively. Comparing the dark blue bars to the red bars and the light blue bars to the pink bars visually indicates the reduction in noise levels with the open-structure design when there is no noise being reverberated from the walls of the structure. There was a 4.3-decibel average reduction for all the frequency ranges with the open structure when comparing the second floor sample location, and a 6.7 decibel reduction for the third floor sampling location.

Figure 4



This overview shows the results of comparing noise in walled and open structures.

Table 2.

Structures	Dust Concentration mg/cubic meter	Production Rate tonnage	Normalized Dust Concentration mg/cubic meter
Masonry	0.20	5,437	$3.7E^{-5}$
Open Structure	0.06	6,905	$8.7E^{-6}$
Steel-Sided	1.87	160.5	$1.2E^{-2}$

Calculated respirable dust concentration per ton of product processed for three structures evaluated.

Discussion

The study results provide only a small picture of the respirable dust and noise levels, and other measurements taken during another time would produce different levels. Nevertheless, considering the data, the most effective structural design of these three building types was the open design. Respirable dust concentrations were significantly lower because the environment acts as the best source of ventilation to dilute and carry away dust generated and liberated during the product sizing process. When production levels are normalized, respirable dust levels at the open structure were more than four times lower than at the masonry structure. Both of these structures had similar screening processes and production levels.

From a noise standpoint, the sound pressure level data measured during the experiments at the two screening tower facilities show that the sound field intensity in both structures decreased with increasing distance from the source. The open-structure design appeared to emulate an acoustic-free field environment. At comparable distances from the source, the sound field level measured in the reverberant environment of the masonry structure tended to be about 5 to 8 dB higher than the level of the sound field in the open-structure design.

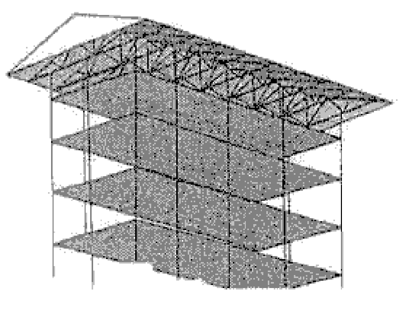


Figure 5 Conceptual drawing of open structure with sufficient overhang to protect machinery and workers from weather.

If an open-structure design is being considered, a number of issues need to be addressed. First, a great effort must be made to provide safety railings and guards to minimize the potential for any personnel falling from the structure. Second, equipment and personnel must be protected from environmental elements such as rain, snow, sleet, and hail. One possibility to minimize this concern would be to design a structure with a sufficient overhang, as conceptually drawn in Figure 5.

It also should be noted that an open-structure design needs to be considered a secondary design. The first approach to lower dust and noise exposures in any structure is to have effective dust and noise source control techniques in place. For dust, this means control techniques that minimize dust generation and liberation and capture major dust sources at their point of origin, before they are allowed to flow out into the plant and contaminate plant personnel. From a noise standpoint, this means using equipment that has been designed with noise dampening components and provides acoustical dampening material when applicable around significant noise-producing equipment and functions. The open design is similar to the total mill ventilation system in that it has the potential to be a global approach to lower dust and noise levels throughout an entire building or structure.

Conclusions

In a field study performed by NIOSH comparing three different types of structures, it was shown that an open-structure design was superior to walled structures when considering both dust and noise levels. From a dust standpoint, the open structure was beneficial because there was no dust gradient when moving up through the building. From a noise standpoint, the open structure was beneficial because it eliminated the reverberation effects of sound waves bouncing off the walls. In the open-structure design, the natural environment acts as an effective method of diluting and carrying away dust liberated during the product sizing process as well as dampens sound waves as they travel out from the structure. No dust plume should ever be visible at an open-structure design. Similarly, major noise sources should be dealt with by using equipment-engineering controls to minimize significant sources.

When building new facilities, obviously the open-structure design is more cost-effective because there are lower material and construction costs involved. Some companies may also want to consider modifying their existing structures with a more open design to further reduce dust and noise levels. If operations are considering the open-structure design, primary dust and noise controls should be paramount to minimize any plant, community, or environmental impact.

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