Case study on the critical physical agents in the cement industry

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Abstract: The Italian Decrees 187/2005 and 195/2006 incorporate the European Directives 2002/44/EC and 2003/10/EC that establish the minimum health and safety requirements regarding the exposure of the workers to the risks arising from physical agents (noise and vibration) at workplace. Prolonged occupational exposure to hand-harm vibration (HAV) from percussive power tools or powered process is associated with an increase occurrence of symptoms of various vascular, neurological and musculoskeletal disorders (MSDs). Furthermore, long-term and intense whole-body vibration (WBV) at frequencies higher than 40 Hz, can cause damage and disturbance of the central nervous system, in particular lower-back morbidity and trauma of the spine. It can also increase the permanent threshold shifts of hearing after a combined long-term exposure to noise. The prevention of injuries or disorders caused by noise and vibration at the workplace requires the implementation of technical, organizing and procedural measures. The above-mentioned directives and national laws establish the qualitative and quantitative methodologies in order to organize the determination and assessment of risks concerning the human exposure to physical agents, preventive and protective measures, plans of information and training of workers. We present here, in accordance with the internal laws and rules, an example of hazards assessment of the most commonly cited physical risks for the workers involved in productive cement plant. It is hoped that the contents of this paper will be of some assistance, guide and support to the physical risks assessment for the cement producers within the EU.

Key Words: physical agents, noise, mechanical vibration, exposure limit values, action limit values, risk assessment, cement works, production units.

1. Introduction

In 2006, the Cement production in Italy totalized 47,436,409 tons (+2,2 % on figures for 2005). Only the North of Italy plant produced 21,857,537 tons of Cement; the consumption was about 47 million tons (+1,8 on 2005) and exports in 2006 amounted to 2,427,616, representing 5.2% of domestic production (+7.5% on 2005). In Italy the industrial units that produce cements are known as cement works; they are productive activities that are classified as class 1 insalubrious[1]; these activities are subject to preventive checks by the Fire brigade for fire risk prevention controls on special productive activities, but these are generally not classified as industries subject to significant industrial accident risk in accordance with the Decrees 175/1988, which transposes the Seveso Directive into national law and subsequent amended, unless large stock of gas oil are present (more than 200 tons). The risk profile refers to activities identified by code Ateco (2002) for the classification of economic activities is 26.51 (cement production); this sector belongs to the "Manufacture of product from the processing of non-metallic minerals" category (Manufacturing). With regard to occupational condition and diseases we must consider that some physical risks are still prevalent as the fourth European Working Conditions (ESWC, 2005) has shown; the ESWC has pointed out that, respectively, 24.2% and 30.1% of all workers reported, in the workplace of the EU-27, being exposed to mechanical vibration and noise for a quarter of time or more during a typical work-day. From the ESWC data results that 24.4% of Italian workforce is exposed to vibration and 23.9% is subject to noise in the workplaces; moreover, in terms of sector, the Construction reports the highest level of exposure to the above mentioned risks, with the Agriculture and Manufacturing sectors also reporting higher than median exposure. The ESWC data show that in the Manufacturing 44.2% and 49.8% of the employed are estimated to be exposed, respectively, to mechanical vibration and noise in the workplace.

[1] According to the Italian Ministerial Decree 5/9/1994: List of the insalubrious industries. Annex, part I, materials and products.

We would value here, started from the above data, the physical hazard (noise and vibration) which are exposed the workers in the cement production unit and identify, also, the critical area in terms of risks in these workplaces.

2. General description of the productive unit

The main territorial areas to which reference was made for the identification of risk factors, preventive and protective measures is about 20 kilometers far from Como city (Merone area). The cement plant has two marl mine on the sides, diametrically opposed respect to the production unit, that are about five kilometers away to the plant. The transportation of crushed marl to the cement works involves conveyor belts. The factory is sited in a valley and is formed by a five macro-areas of large building of considerable height connected to one another by a transportation system for material being stocked and processed. Only the plant area is about 23.5 hectare and total workers involved in cement production cycle are 140 in all, thirty of them employed in three-eight hour shift. The production of cement in the unit, related to the multinational producer of building materials, that we have considered in this work, performs the production cycle with the dry[2] and the semi-dry[3] process using two different semi-horizontal rotating kilns (n.1&2); this plant in the 2006 was produced 1.6 million tons of cement (on 3,300,000 tons total produced in Italy with 3 plants of same group). The central phases of cement production are completely automated and the workers present is mainly engaged in machinery monitoring operations on a patrol basis, circulating between the various productive departments with the aim of overseeing the functionality of the machine, safety and control devices and with the task to signal any malfunctioning, maintaining constant contact with the control room. At last, part of cement produced in the plant has bagged in 25 kg sacks, which are then packed on pallets and loaded onto good vehicles; the remained part is delivered loose to customers with tankers. These are loaded by means of a flexible hose that connects the storage silos directly to tankers parked on the yard.

[2] This means that the raw materials, once grounded and homogenised, are introduced into the kiln (n.1) in a dry powdery state called perlite.

[3] Meaning that the raw perlite is dampened, in order to form small agglomerate of perlite and water, which are introduced into the kiln (n.2) for firing.

3. Contents of social Directives on physical agents

In Italy, Following the implementation of both EU Directive on the minimum safety requirements regarding the exposure of workers to the risk arising from the physical agents (vibration and noise), respectively in October 2005 and in December 2006, employers were required to perform "a suitable and sufficient assessment of risk", including estimation of worker daily vibration and noise exposure level, to determine whether the exposure action value (EAV) or exposure limit value (ELV) were likely to be exceeded during normal working. In this way the employer shall be identify what measures must be taken in accordance whit the EU Directives, national laws and practices. An adequate assessment will be possible by use of noise and vibration emission/exposure information on the working area and machine type used by workers during the operation or activity in object. In particular, the evaluation of workers exposure to mechanical vibration and noise is based on the calculation of the exposure levels; the values given in the Directives (and transposed into national laws) are expressed in terms of an eight-hour exposure. In fact, for hand-transmitted vibration (HAV) the daily exposure, standardized to an eight-hour reference period, A(8), shall be:

- 2.5 m/s^2 as action value;
- 5.0 m/s^2 as limit value.

The required method for measuring and evaluating hand-harm transmitted vibration is as defined in ISO 5349-1:2001 and ISO 5349-2:2001.

Moreover, for whole-body vibration (WBV) the daily exposure, standardized to an eight-hour reference period, A(8), shall be:

- 0.50 m/s^2 as action value;
- 1.15 m/s^2 as limit value.

To note that the required method for measuring whole-body vibration is as defined in ISO 2631-1:1997; in this case the evaluation of exposure is based on the calculation of A(8) expressed as an equivalent continuous r.m.s. acceleration over an eight hour period. Furthermore, the previsions set forth in Italian regulation regarding the control of noise in the workplace (Decree 195/2006) are applied to all public and private activities in which subordinate workers or equivalent operate; this regulation requires to take specific action at certain limit values. These relate to 1) the levels of exposure to noise of your employees averaged over a working day or week and 2) the maximum noise (peak sound pressure) to which employees are

exposed in a working day. The daily or weekly levels and peak sound pressure are fixed at:

- lower exposure action values: $L_{EX,8h}$=80 dB(A) and p_{peak}=135 dB(C) re 20 μPa;
- upper exposure action values: $L_{EX,8h}$=85 dB(A) and p_{peak}=137 dB(C) re 20 μPa;
- exposure limit values: $L_{EX,8h}$=87 dB(A) and p_{peak}=140 dB(C) re 20 μPa;

Where the daily noise exposure level ($L_{EX,8h}$) is the average noise exposure level for a nominal 8-hour working day as defined by ISO 1999:1990 and the peak sound pressure (p_{peak}) is the maximum value of the "C"-frequency weighted instantaneous noise pressure. Note that the exposure limit values above mentioned take account of any reduction in exposure provided by individual hearing protections (earmuffs or earplugs).

4. Assessment of the risks

The overall objective of this investigation was to determine currently achievable vibration and noise emissions and likely operator daily exposure levels associated with different kinds of machine used in the cement works. Frequency analysis of the vibration data and direct observation provided information to reduce operator exposure by appropriate implementation of technical, organizational and procedural measures. As regards the vibration exposure analysis, we have reported here some examples of different types of tool or machine used as they perform their normal operation in the production unit; this investigation was to target a number of on-site examples of specific machine, as encountered, in the area of cement bagging and palletizing, handling operation and in mechanical workshop used by maintenance of the plant. For each on-site example the objective was to determine WBV and HAV emission and operator exposure levels associated with machine operations. To note that it is possible to compare the data derived by these measures with the typical weighted values produced by the same or similar kind of machines that are, in part, available at the internet addresses:
(http://vibration.arbetslivsinstitutet.se/eng)
(http://www.las-bb.de/karla/index.htm)
(http://www.ispesl.it/test/index.asp)
Finally, the control of noise at workplace due to Italian Decree 195/2006 imposes in case the risks arising from exposure to noise cannot be prevented by other means, that the employer provides information and training to employees (and their representatives) and provides hearing protection available for the workers involved. Particularly, where noise exposure exceeds the lower exposure action values, the employers (or their delegates) shall provide individual hearing protectors available to workers; whereas noise exposure matches or exceeded the upper exposure action values, individual hearing protectors shall be used (must be worn) to workers. Where, exceptionally, an employee's exposure has, despite the program of controls, exceeded the exposure limits ($L_{EX,8h}$) of 87 dB(A) and (p_{peak}) of 140 dB(C), the employer (or their delegate) must take immediate action to reduce exposure below the exposure limit value and prevent it being exceeded in the future.

4.1 Whole Body Vibration

Acceleration levels were measured simultaneously in three mutually-perpendicular directions (X-longitudinal, Y-transverse, Z-vertical) at one location on each target machine, namely upon the surface of the operator's seat. Details of each machine and the resulting WBV levels are presented in the *table 1*.

Table 1

Machine / N. / Power	Average rms acceleration (m/s^2)				Time to EAV (hr)	Time to ELV (hr)
	X	Y	Z	Major axis		
1. Linde H30/diesel	0.327	0.371	0.790	Z	3.2	16.9
2. Linde H40/diesel	0.503	0.654	1.11	Z	1.6	8.5
3. Linde H70/diesel	0.447	0.530	1.12	Z	1.5	8.4
4. Linde E30-02/electric	0.358	0.579	0.810	Z	3.0	16.1
5. Crane Prim-45 t./electric	0.132	0.085	0.221	Z	24	24
6. Caterpillar CAT902/diesel	0.553	0.555	0.850	Z	2.8	14.6
7. Sibilia SU400/diesel	0.666	0.642	0.630	X	2.3	12.2
8. Dulevo 200-4/diesel	0.180	0.205	0.650	Z	4.7	24

In the operational phases as bagging and palletizing of powder the workers use the lift trucks (see *Tab.1*, Machines N.1,2,3&4) in order to reduce/avoid the musculoskeletal risks derived by the material manual lifting and/or handling the clinker; the lift truck are also used to transport work equipment in case of new plant installation or maintenance operations. Furthermore, during the firing of the blend in the kiln, the main fuel used to fire is the coal (pulverized), this is transported to the production plant in bulk on lorries and is unloaded into special unloading hoppers, from which it is removed by conveyors belt, bridge crane with grab jaw (*Tab.1*, Machine N.5) and skid-steer loaders (Mach. N.6&7). Besides, in the operation of

cement bagging and palletizing, power can be dispersed, resulting in worker exposure, especially in the case of accidental spillage and maintenance of productive lines; for these reasons the plant is monitored constantly, exhausted systems were used frequently to clean the plant department and road sweeper machines (see *Table 1*, Machine N.8) are in used, frequently, to clean production unit yard.

4.2 Hand Harm Vibration

Accelerometers were mounted on the tools so they were measuring the vibration transmitted to the hands in all condition of use by workers; at each measurement location, three piezoelectric accelerometers were oriented in orthogonal axes. The vibration analyzer produced a one-third-octave band frequency spectrum of r.m.s. acceleration for each measurement axis; the frequency weighting, as defined by ISO standard 5349-1:2001, was applied to each spectrum to give the hand-harm weighted acceleration value for each measurement axis. Summaries of the HAV measurement results are presented in table 2.

Table 2

Tool / N. / Power	Average rms acceleration (m/s^2)			Time to EAV (hr)	Time to ELV (hr)
	X	Y	Z		
9. Rupes PD 30-02/electric	1.057	2.25	3.48	2.8	11.2
10. Rupes TR10/electric	1.41	1.71	1.07	7.6	24
11. Usag 940D/pneumatic	10.33	11.14	13.32	0.1	0.6
12. Chicago CP894/pneumatic	5.86	4.60	4.46	0.7	3.1
13. Rupes AR11/electric	0.59	1.13	0.77	15.6	24
14. Dewalt DW476/pneumatic	2.41	3.98	3.10	2.1	8.5
15. Jeorges Renault 321M/pneumatic	7.35	17.16	14.29	0.1	0.6
16. Jet Chiesel JEX-28/pneumatic	9.20	13.80	9.90	0.2	0.9
17. Chicago PN/pneumatic	14.77	21.8	12.55	0.1	0.4

Typical metalwork is performed for the mechanical maintenance (ordinary and extraordinary) of cement units; we have identified the following main risk factors potentially present in this work phase derived by the use of:

- portable tools in the ordinary maintenance operation chiefly on mill, transporters, silos hopper and metal structures; these operations are carried out by the use of pistol-grip drill (see *Table 2*, Tools N.9&10), screwdrivers (Tools N.11&12), angle grinders (Tools N.13&14) by operatives;
- pneumatic hammer for the scaling or demolition of the refractory-brick inside the kilns (*Table 2*, Tools N.15,16&17) by operators .

4.3 Noise

As already mentioned, the A-weighted L_{eq} and the C-weighted peak are used to assess the operator exposure relative to the action and limit values given in current Italian legislation (Decree n.195/2006, article 2). The C-weighed Leq and SNR[4] difference can be used to estimate the effectiveness of personal protective hearing (PHPE). In fact, according to standard EN 458:1995, the method SNR compare the level of action L_{act} (that must not exceeded lower exposure action values: L_{Aeq}=80 dB(A) and p_{peak}=135 dB(C) re 20 μPa) with the mentioned difference (L_C-SNR) in order to evaluate the suitability of the hearing protection devise. The above mentioned standard establishes the following criteria to evaluate the decree of protection of PHPE (see *table 3*).

Table 3

Effective level at the ear (in dBA)	Estimated protection
$L_{act}<(L_C\text{-SNR})$	Inadequate
$L_{act}-5<(L_C\text{-SNR}))\leq L_{act}$	Acceptable
$L_{act}-10<(L_C\text{-SNR})\leq L_{act}-5$	Good
$L_{act}-15<(L_C\text{-SNR})\leq L_{act}-10$	Acceptable
$(L_C\text{-SNR})\leq L_{act}-15$	Hyper-protection (too high)

Noise measurements were made to the side of the operator with an integrator-phonometer (conforms to IEC 651 and 804, type I). The measurement parameters are:

- L_{Aeq} (the level of equivalent acoustic pressure of the noise to the A curve);
- L_{Ceq} (the equivalent level of acoustic pressure of the noise weighted according to the C curve)
- p_{peak} (Maximum C-weighted peak pressure).

Granted that in the following analysis we must considered that the layout of cement works is not completely standardized and the density of machines and workers (together) varies, with the attendant variation in the noise exposure attributable to the operation developed nearby productive machines. Extract of results of noise measurements, for the bagging and palletizing dept., are presented in *table 4*.

[4] It expresses with a single value, in dB, the simplified noise reduction of the hearing protection equipment that must be provided by the manufacturer of the earmuffs and earplugs

Table 4

Installation/N./Position	L_{Aeq} (dBA)	Max p_{peak} (dBC)	L_C –SNR (dBA)	PPHE (protection)
18. Materials unloading area	87.7	107	68.9	Acceptable
19. Cement silos area	83.4	121	65.1	Acceptable
20. Compressors cab / pos.1 (nearby)	87.8	110.9	70.6	Good
21. Compressors cab / pos.2 /	83.2	105.3	67.7	Acceptable
22. Bagging Machine / N.2	84.0	108.1	67.9	Acceptable
23. Bagging Machine / N.1	86.0	109.3	70.0	Acceptable
24. Unloading Conveyors area	80.3	104.6	66.2	Acceptable

It must be considered that the noise exposure of workers in the cement works varies considerably but the majority of their exposure should be attributable to the operations of loading and crushing of the coarse marl, transportation, grinding and homogenization of unfired powdery (perlite), to the rotation of kilns and to the burners, the materials moved inside the kilns, etc. However, in these phases of work processes there are no fixed workstation, rather workers follow a patrol schedule to check the plant and cleaning operations. Our interest is put on the cement bagging and palletizing department, where the cement produced is bagged in sacks and then stacked one on top of another to pallets that are stored in the internal warehouse. The work-emplacement near the air compressors cab (see tab.4, pos. N.20), the unloading area (pos. N.18) and the bagging machines (pos. N.22&23) are resulted the critical areas in terms of equivalent sound pressure level (L_{eq}) but, however, it not exceeded the daily total personal noise exposure ($L_{EX,8h}$) of the second (upper) action level value. Also, the measurements shows there is not a risk of peak sound levels exceeding 137 dB(C). To note that for all position it is provided, by internal safety procedures, that the operators involved in every working site used duty helmet with muffs or hearing protectors that should be chosen to give right protection.

5. Conclusions

Where, exceptionally, the daily exposure limit value due to noise and vibration in the workplace will be exceeded, the employers must take immediate action to reduce exposure below this limit values and amend the organizational and technical measures to prevent it being exceeded again. As the results of this survey show, there are potential risks for workers of exceeding the daily exposure limit value if the pneumatic tools, utilized in the operation of maintenance and demolition, are used for less than ½ hour on height hour-shift per day in the cement works. According to what we said before, we can put in evidence critical areas which need more inquiries and studies on physical agents to avoid occupational disease to workers (i.e. operatives) employed at use of the hand-held portable power tools in some limited areas of the cement production, but also and chiefly in all the sectors where there a large use of the pneumatic percussive power tools.

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