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COMPARISON OF HUMAN SAFETY RISKS BETWEEN OLD AND NEW CONCRETE MIXING PLANT

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Abstract

One of, if not the most important service sector today is construction. It is constantly changing, both in terms of materials and workforce. That is why it is important to monitor it from a health and safety perspective. New materials, products and equipment are regularly introduced to the market, and it is essential not only to review them in advance, but also to monitor their continued use from a safety perspective. From the point of view of building materials, if we look only at the increased battery production and the construction of the halls required for this, reinforced concrete, of which thousands of m^3 are produced every year, has an absolute advantage. The production of a simple reinforced concrete element is a very long process, from the raw material extracted to the delivery of the finished product to the construction site. In the 21st century, it has become clear to us that the future lies in robotisation and the constant introduction of electronics. The more machines, the more hazards. As in any other factory, the improvements in the plant under review are being made in parallel with the need to ensure safety at work. Newly installed and/or commissioned machines and equipment are subject to preliminary and periodic inspections and maintenance. This is no different for the concrete mixing plant of the company under investigation, which is constantly being improved and refined in order to develop the most efficient and safest production technologies. The aim of our work is to illustrate the new Italian-made concrete mixing plant installed when the existing mixer was replaced in the 1990s, and to show how this improvement and the use of modern technology have enabled the company to reduce the risks and make the plant safer from the point of view of health and safety.

Keywords: *occupational safety, human safety, concrete mixing plant, introduction of new technology*

1. Introduction

The most widely used building material today is concrete. It is used in everything from foundations, slabs and footings to the supporting structures of skyscrapers. It is used in every area where construction activity takes place. Its most basic use is in the foundations of buildings. Due to its high compressive strength, it is able to absorb, support and distribute the weight of the building to the ground below. One of its most advantageous properties for foundations, slabs, beams, bridges and many other applications is that it can be set in almost any geometric shape when used with the right formwork. It is also important to note that the concrete itself, or the precast element, requires the addition of admixtures according to its intended use. These additives are an important part of concrete technology. If easier mixing can only be achieved by adding more water, the strength and, of course, the quality of the concrete may be impaired. The development of admixtures has always been linked to the water-cement ratio and the quality of concrete. They have been standardised, like almost all other building materials, but their use in quantity is, in my opinion, more based on experience. Admixtures are liquid or powdery substances mixed into concrete in small quantities, which affect some properties of the concrete favourably and others unfavourably. Dual action admixtures have two main effects.

Types of additives according to product standard MSZ EN 934-2:

- Single acting additives:
  - plasticizer,
  - disburser,
  - stabilising,
  - air bubbles,
  - knitting accelerator,
  - accelerator,
  - knitting delay,
  - sealant.
- Multifunctional additives:
  - a plasticizer with a side effect of delaying curing,
  - bind-delaying side effect of a flow agent,
  - plasticizer with accelerating side effects.

They all play an important role in the manufacturing, bonding and solidification processes. They depend on the intended use of the concrete and the installation of the element. Are they installed above or below ground, protected from water, wind, frost, monolithic or precast elements (Pankhardt and Kovács, 2013; Balázs, 1994).

2. Construction of concrete mixing plants

Mixing plants are classified in many different ways. We distinguish between small (<40 m^3/hour), medium and large (>100 m^3/hour) capacity plants, depending on whether the process equipment is placed side by side or above each other, horizontal, vertical or mixed. They may be either intermittent or continuous, and may be stationary or mobile mixing plants. The majority of modern plants have automated, computerised control. Their design is usually related to their capacity, with mobile plants generally having a low to medium capacity and on-site plants a high capacity. Concrete plants in use today meet not only the quantity requirements but also the quality requirements of the concrete through their computer control systems (Forrai, 2003).

Structural units of concrete plants:

- open-air depots, closed silos for storing raw materials,
- Loading/transport equipment for filling storage sectors, sectors,
- material handling machines that transfer the raw material from the sector to the weighing system,
- feeding and weighing equipment,
- mixing machine,
- control equipment,
- the building housing the system,
- additional units required for operation, e.g. plumbing system, control cabin.

The different fractions are stored separately in outdoor or closed depots. From these spaces, the additives are transferred to the pre-storage bins, the layout and filling of which may depend on the size and type of mixer. Cements and powdered material are stored in silos. These silos are filled pneumatically, either by the concrete factory's air network or by the tanker truck's compressor. To avoid binding of the powder materials, the silos are often equipped with vibrators or air-loosening systems.

Weighing is done by weight, one by one. This process is carried out by electronic load cell equipment. Quantitative adjustments of the components can be made from the control panel.

Additives are most often fed by sector lock or vibratory feeders driven by a pneumatic working cylinder, while powder materials are fed by a cement conveying auger with a fine feeder and speed control drive.

As before, in many places, water dosing has been replaced by electronic scales, neglecting the previous volumetric measurement. Filling these tanks now requires a strictly fine dosage. In the case of outdoor depots, the experience of the operator is particularly important with regard to any additives that may be wet. Adherence to the amount of mixing water required by the recipe and the addition of wet sand and gravel can produce a diluted concrete. Chemicals are usually added to the mixing water to the accuracy of the concrete recipe.

The three most common types of plants are mobile, semi-mobile and continuous concrete plants. Mobile mixing plants are usually horizontally arranged and the structural units are designed to be transported by trailer and then assembled at the new installation site.

In the case of the mobile mixing plant shown in *Figure 1*, the different fractions are stored in open-air depots, from where they are transferred to the appropriate storage compartments by means of loading machines. From there, the individual particle sizes are weighed on a weighing conveyor by means of sector-lock feeders. Once the aggregate weighing is completed, the conveyor belt transports the material to the collection hopper, which is then hauled up to the level of the mixer by a winch. The binder is transferred from the silos by a cement conveyor pulley to the weighing scale above the mixer, from where it is fed directly into the mixer.

In the case of installed concrete plants, graded materials are either directly transferred from the transport vehicle or from the outdoor depot to the storage silos *(Figure 2)*. The material is usually extracted from the depots by means of a conveyor belt underneath. The depots can supply the concrete needs of 2-3 shifts.

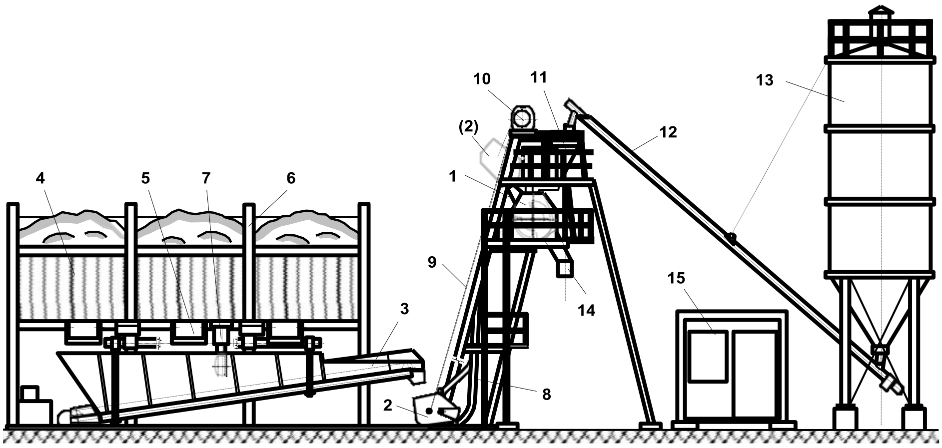

Figure 1. *Relocatable concrete mixing plant. 1. horizontal axis mixing machine, 2. aggregate collecting hopper, 3. weighing belt, 4. aggregate storage, 5. sector lock, 6. partition, 7. weighing display instrument, 8. collecting hopper lift, 9. rope, 10. winch, 11. cement weighing scale, 12. cement conveyor pulley, 13. cement silo, 14. concrete surrender, 15. operator's cabin* (Rácz, 2011)

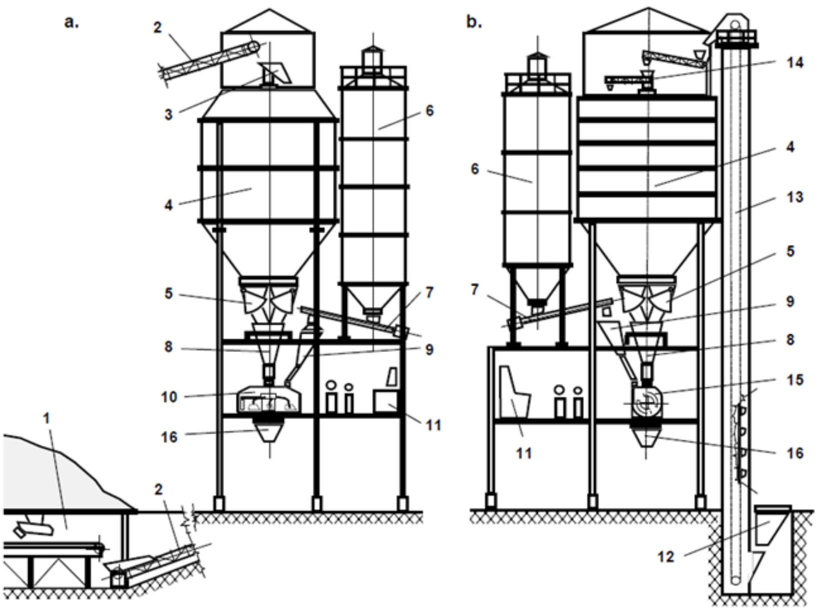

Figure 2. *Tower concrete factory. 1. belt conveyor, 2. conveyor belt, 3. rotary surrender, 4. compartmentalized aggregate silo, 5. sector lock, 6. cement silo, 7. cement conveyor pulley, 8. aggregate weighing scale, 9. cement weighing scale, 10. vertical axis mixer, 11. control panel, 12. dispatching garage, 13. vertical elevator, 14. distribution conveyor, 15. horizontal axis mixer, 16. aggregate storage* (Rácz, 2011)

The silos are divided radially into compartments. Level sensors are used to estimate the quantity of material contained. These instruments can either give a signal to the operator or start filling the compartment themselves, which can be done by a rotating feeder or a rotating conveyor belt. From here, after weighing, the material is conveyed via a surge conveyor to the mixer and from there to the transport vehicle.

Finally, continuous factories are now used to produce large quantities of concrete. In these, the batching bins are always filled with front-end loader. Belt weighers are placed under each compartment, and from there the fractions are conveyed to the mixer via a collecting conveyor. A conveyor pulley is also used here to feed cement. Water is continuously added to which the desired amount of chemicals is mixed. After mixing, the concrete is fed into a conveyor (Rácz, 2011).

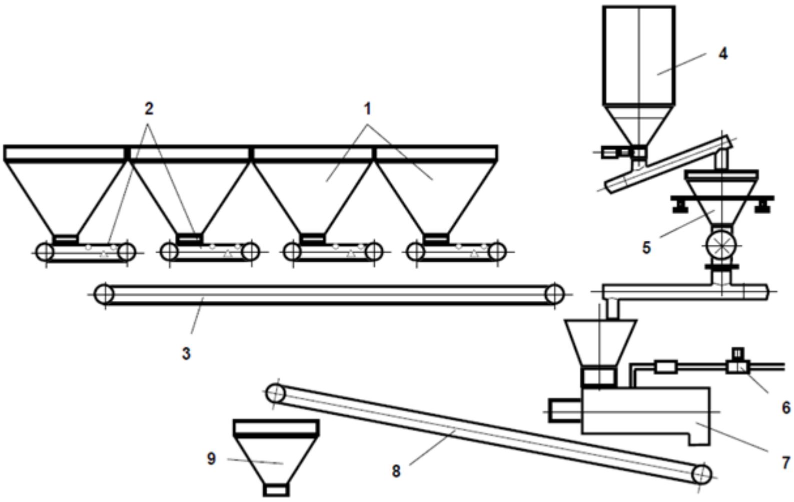

Figure 3. *Continuous concrete mixing plant. 1. batching bins, 2. belt weighers, 3. collecting conveyor, 4. cement silo, 5. cement weighing conveyor, 6. water metering valve, 7. continuous mixer, 8. delivery conveyor, 9. concrete storage tank* (Rácz, 2011)

3. Risk assessment and evaluation

Rethinking the technology of the installation: because of the myriad of processes involved, we have considered the steps that we consider the most risky

Transfer, receipt and inspection of mixer I. at shift change,

Start of mixer II,

III. Dosing of materials,

IV. conveyor belt,

V. additive transport container,

VI. concrete mixing,

VII. Transport and batching of concrete using an overhead conveyor,

End-of-shift maintenance and cleaning at the end of shift VIII.

Risk analysis table structure:

- Technology serial number;
- use operation;

- source of danger;
- planned risk;
- Comment;
- a risk reduction proposal;
- changed risk.

General hazards according to Annex B of ISO 12100:2011:

1. Mechanical hazards: angular parts, moving element approaching a fixed part, falling objects, gravity, height above ground, moving elements, rough slippery surface;
2. Electrical hazards: arcing, overloading, parts becoming active in fault conditions, short circuit;
3. Thermal hazards: high or low temperature objects or materials;
4. Noise risk: presumed not to exist;
5. Vibration hazard: presumed not to exist;
6. Radiation risk: presumed not to exist;
7. Hazards of the substance and preparation: liquid, smoke, dust;
8. Ergonomic hazards: approach access, design or placement of displays and screens, design, placement and identification of controls, effort, posture, repetitive activity, visibility;
9. Hazards related to the environment in which the machinery is used: lighting, damp, dirt, snow, water, frost;
10. Hazard combinations: not suspected.

Table 1. *Risk matrix* (authors' own editing)

Risk matrix				
Injury severity/Likelihood of occurrence	**A1 No personal injury**	**A2 Minor personal injury**	**A3 Significant personal injury**	**A4 Serious personal injury**
B1 Unlikely	1Low	1	2	3
B2 Possible	1	2low	3	4
B3 Probable	2	3	4	5
B4 Inevitable	2	4	5	6
Value of risk	**Risk level**	**Outcome/What to do**		
1–2	Low	Acceptable risk, does not necessarily involve action		
3–4	Medium	Risk mitigation with necessary timeframe and responsibilities		
5–6	High	Immediate risk reduction is required, including by banning use and eliminating the source of the hazard		

One of the main reasons for replacing the mixer, in addition to the increased production volume, was to make it safer from a health and safety point of view. In many respects, the "RÉGI" concrete mixer, which was still in production in 1997, was considered obsolete. The accessibility of the individual units was not properly designed. Exit points were scarce, doors could be locked with a simple key, which was often lost or not locked. It is also very important to note that with this outdated security system, it was possible to gain access to various pieces of equipment while they were still in operation. This danger is perfectly eliminated by the "NEW" mixer with its magnetic doors, which can only be opened by employees with the appropriate access authorization card.

Table 2 shows some examples of risks that have improved dramatically and those that remain.

Table 2. *Comparison of the main hazards of "RARE" and "NEW" mixers* (authors' own editing)

Technology serial number	**Danger source**	**Risk value**	
		"RARE"	**"NEW"**
I.	**A-1;2;8:** Accident caused by careless handling by an unauthorised worker, for example when the operator is cleaning the mixing drum.	3 medium	1 low
II.	**C-1;2;7:** Starting the machine with the mixer door open, which can cause entrapment, spillage and consequent accidents.	4 medium	1 low
III.	**B-1;8;9:** Unlighted areas are unsafe for loading and the ramp to access the sectors is in poor condition, which could result in an accident.	3 medium	3 medium
III.	**C-1;8;9:** It is unsafe to walk on the ramp. There is a risk of falling or tripping.	3 medium	3 medium
VI.	**A-1;2;7;9:** Accident resulting from access to the operating machinery, spillage, electrical hazard.	4 medium	1 low
VII.	**A-1:** unauthorised access to the parking position of a suspended bath and consequent fall, can cause the bath to be knocked over or pushed off the stand while it is in operation.	3 medium	1 low
VII.	**B-1:** due to overhead traffic, any failure, track failure due to a drop of the curtain is an accident hazard.	3 medium	3 medium
VIII.	**A-1;2;8;10:** Accident due to working with a chisel while cleaning a mixing drum, ergonomic hazard due to incorrect posture, concrete debris falling from the main discharge onto the worker.	3 medium	1 low
VIII.	**D-2:** Workers may be electrocuted during maintenance tasks.	3 medium	1 low

The comparison shows that there are still critical points that can be modified, but there are also units where there is a residual risk, such as the overhead danger of the curtain, which, if for some reason it were to fall off, would result in a serious accident. Of course, the technology is designed and engineered to be as safe as possible, so this is unlikely to happen. The only thing that can be done, apart from sounding an audible alarm, to alert the worker to the approaching conveyor is to place a safety light at the bottom of the tub, which will indicate its current position on the traffic route at ground level by a red light.

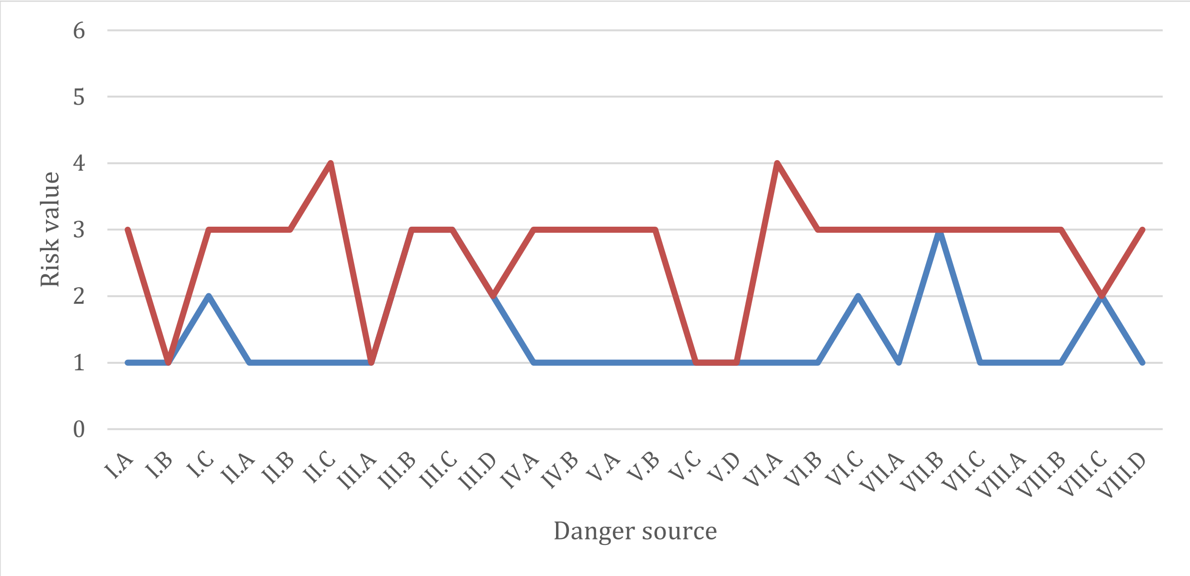

Figure 4. *Comparison of risk values of "OLD" and "NEW" mixers (yellow – OLD, blue – new)* (authors' own editing)

4. Summary

We compared the human safety risks of old and new concrete mixing plants through risk assessments of mixers.

In every industry, progress is the result of continuous improvement. One of today's most evolving areas is the introduction of electronics and computer control into most technologies. When we talk about concrete mixing, the first thing that comes to mind is probably a simple concrete mixer seen on construction sites, but then there are the concrete and precast plants that produce huge volumes on a daily, weekly, monthly and annual basis. That is why it is important for these sites to have modern and safe technology. From the operator, machine operability, mixing equipment placement and technology, material feeding, finished product delivery, environmental and ergonomic factors, and maintenance feasibility are all vital design considerations. Concrete mixing plants designed according to a "RARE" and a "NEW" technology have been studied taking these into account. Each unit has been designed to ensure that the risky elements of the replaced mixer are of the highest quality and safety. Critical points and residual risks still remain, and their elimination will require the development of a new technological line, which will become a task in the future when new scientific developments will be available.

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