

Safety in ready mixed concrete industry: descriptive analysis of injuries and development of preventive measures

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Abstract: Ready mixed concrete (RMC) industry, one of the barebones of construction sector, has its distinctive occupational safety and health (OSH) risks. Employees experience risks that emerge during the fabrication of concrete, as well as its delivery to the construction site. Statistics show that usage and demand of RMC have been increasing along with the number of producers and workers. Unfortunately, adequate OSH measures to meet this rapid growth are not in place even in top RMC producing countries, such as Turkey. Moreover, lack of statistical data and academic research in this sector exacerbates this problem. This study aims to fill this gap by conducting data mining in Turkish Social Security Institution archives and performing univariate frequency and cross tabulation analysis on 71 incidents that RMC truck drivers were involved. Also, investigations and interviews were conducted in seven RMC plants in Turkey and Netherlands with OSH point of view. Based on the results of this research, problem areas were determined such as; cleaning truck mixer/pump is a hazardous activity where operators get injured frequently, and struck by falling objects is a major hazard at RMC industry. Finally, Job Safety Analyses were performed on these areas to suggest mitigation methods.

Key words: Dust, Ergonomics, Industrial accidents, Occupational health and safety management system, Work environments, Ventilation, Risk management

Introduction

Occupational injuries and illnesses in high risk sectors are considerably prevented with the maturation of the legislation, improvement of technology and development of occupational safety culture. However, this is not always the case particularly in project-based sectors, where risks are constantly changing compared to factory based production. For instance, construction, which is a project-based sector, holds higher ranks in fatal occupational injuries compared to other sectors. In the United States of America

(USA) Out of 4,251 worker fatalities in private industry in calendar year 2014, 874 or 20.5% of them were in construction—that is, one in five worker deaths were in construction. This amount holds the first place compared to the other sectors¹⁾. The situation is not so different in other countries. Bomel²⁾ notes that in Japan, construction accidents account for 30%–40% of the overall industrial accidents, with the total being 50% in Ireland and 25% in the United Kingdom. In Italy, fatal accidents in the field of construction represent 25% of the total accidents occurring in the industry³⁾. In China, there were an estimated 3,000 construction industry fatalities in 2003 alone⁴⁾. Globally, construction workers are seemingly three times more likely to be killed and twice as likely to be injured as workers in other occupations. Thus, construction industry needs to be

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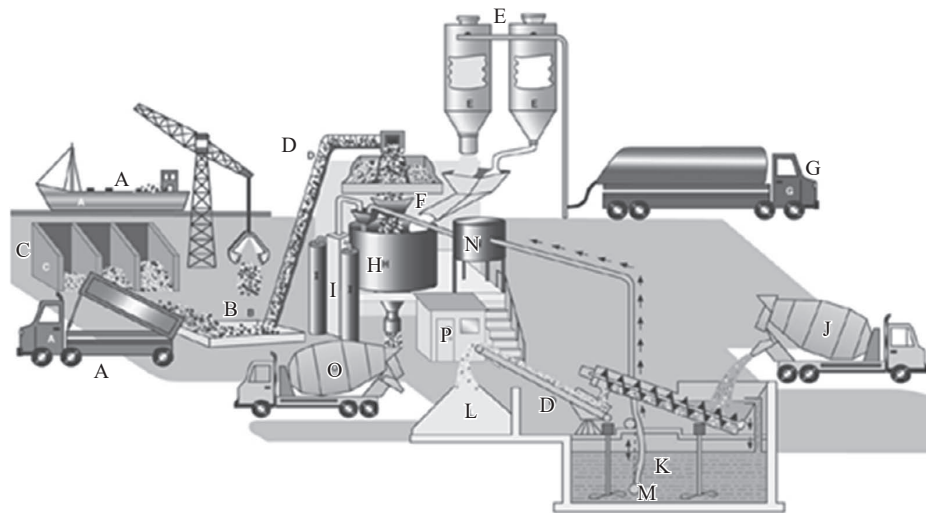
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Table 1. Country data (Source EUROSTAT: <http://ec.europa.eu/eurostat>)

Country	Total RMC country millions of m ³		
	2011	2012	2013
Austria	10,5	10,6	10,5
Belgium	11,6	12,5	12,5
Czech Republic	7,5	6,9	6,5
Denmark	2,1	2,0	2,3
Finland	3,0	2,7	2,7
France	41,3	38,9	38,6
Germany	48,0	46,0	45,6
Ireland	2,4	2,4	2,4
Israel	12,0	13,0	14,0
Italy	52,6	39,9	31,7
Japan	88,0	92,0	99,0
Netherlands	8,8	7,3	6,6
Norway	3,5	3,7	3,8
Poland	23,7	19,5	18,0
Portugal	6,1	3,7	2,7
Russia	40,0	42,0	44,0
Slovakia	2,3	1,9	1,7
Spain	30,8	21,6	16,3
Sweden	3,3	3,3	—
Switzerland	12,5	13,0	12,0
Turkey	90,0	93,0	102,0
United Kingdom	19,2	17,6	19,6
USA	203,0	225,0	230,0

further analyzed for reducing accident rates. Analyses and improvement efforts should include not only construction but also other sub-sectors such as ready mixed concrete industry, prefabricated construction industry, brick plants etc. These sectors should be examined separately because production processes are different from each other, as well as the potential hazards and recommended measures.

Ready Mixed Concrete (RMC) industry, which is one of the most essential sub-sectors of modern construction, is responsible for producing a construction material crucial for constructing engineering structures, such as roads and bridges, homes and high-rises. Combining of fine and coarse aggregates, cement and water is creating this important building material⁵⁾. Most developed countries prefer to use RMC instead of conventional concrete production because of the advantages of RMC such as: speedy construction through programmed delivery at site, consistency in quality through accurate & computerized control of sand aggregates and water as per mix designs, mechanized operation with consequent economy, minimizing cement wastage due to bulk handling, reducing the labor cost and site supervising cost, proper control and economy in use of raw material resulting in saving of natural resources and reducing project time resulting in savings in all aspects⁶⁾. Due to



A: Aggregate delivery
 B: Aggregate receiving hopper
 C: Aggregate storage
 D: Conveyor belt
 E: Cementous material storage
 F: Weigh hopper
 G: Cement delivery
 H: Mixer

I: Admixtures
 J: Ready mix truck with concrete
 K: Recycled water
 L: Reprocessed aggregate
 M: Pump
 N: Water storage
 O: Concrete loaded in ready-mix truck
 P: Control room

Fig. 1. Ready Mix Concrete Production³⁴⁾

the reasons listed above, this product is increasingly being preferred specifically in modern construction. Increasing of RMC production at different countries is shown in Table 1⁷⁾. According to country data, U.S.A. is the top RMC producer in the world, followed by Turkey and Japan.

Ready mix concrete plants have many more components to it. In other words, it is the assembly of tools and machines such as mixers, cement batchers, aggregate batchers, conveyors, radial stackers, aggregate bins, cement bins, heaters, chillers and cement silos as shown in Fig. 1. So, operations partially take place in the production area, where RMC is produced and loaded into mixer trucks. The second part of the operations continues outside the production area, where truck mixer transports the materials to a construction site and truck operator assists with the casting process.

Despite its increasing growth and popularity, RMC industry has its distinctive risks in terms of occupational safety. The employees of this sector experience the risks that emerge not only during the fabrication process of concrete, but also during its delivery to the construction site. Potential hazards for workers in concrete manufacturing can be listed as: Eye, skin and respiratory tract irritation from exposure to cement dust, overexertion and awkward postures (ergonomics), slips, trips and falls, chemical burns from wet concrete, loss of stability, cutting and severing, hazards generated by vibration and radiation. The source of these hazards are usually derived from system failure, inadequate safety guards on equipment, inadequate lock-out/tag out systems on machinery (mechanical and electrical hazards), ejection of parts or material, shearing hazards generated by noise, stabbing or puncture, friction or abrasion, high pressure fluid injection, combined hazards^{8,9)}.

RMC industry in U.S.A. still suffers from safety problems, regardless of leading the world in RMC production with 5,000 plants and 68,500 trucks⁵⁾. According to OSHA, more than 250,000 people work in concrete manufacturing in US. Unfortunately, of the hundreds of thousands who work in concrete product manufacturing, tens of thousands have experienced a job-related injury, illness or death. Over 10 percent of those workers - 28,000 - experienced a job-related injury or illness and 42 died in just one year⁸⁾. The latest Bureau of Labor Statistics data (as of October, 2013) shows the RMC industry with an incident rate of 4.8¹⁰⁾.

There has been a tremendous growth in RMC production, particularly in Turkey, the second largest RMC producer. The production volume in Turkey rose from 26.542.905 m³ to 107.000.000 m³ over a period of 16 years

Table 2. RMC Industry's profile in Turkey

Data from year	Total RMC millions of m ³	Number of Producers	Number of Plants
1988	1,5	25	30
1993	10	70	110
1998	26,5	166	341
2003	26,8	238	429
2005	46,3	277	568
2006	70,7	409	718
2007	74,4	477	845
2008	69,6	462	825
2009	66,4	467	845
2010	79,6	500	900
2011	90,0	520	945
2012	93,0	540	980
2013	102,0	580	1,040
2014	107,0	600	1,080

as seen in Table 2. The number of the RMC plants also rose from 341 to 1,080 in the same period of time¹¹⁾. Nevertheless, occupational safety and health measures in Turkish RMC were not adequate to meet this production growth¹²⁾. There have been numerous injury cases over the last ten years that ready mix concrete truck drivers were involved. However, records of these incidents are not being properly reported and recorded for future analyses by majority of Turkish RMC companies. Since safety and health is a rather new topic in RMC industry, statistical and academic studies are rarely found. Besides, there is high demand for training and consultation regarding occupational safety by RMC companies.

Academic studies on RMC safety are not abundant either in other countries. A state-of-the-art research was performed on this topic and no articles printed on scientific journals discussing safety problems in RMC industry were encountered. It was also observed that there is a lack of practical knowledge that contains a holistic assessment of hazards and risks that might occur during manufacturing and handling of RMC. Only, guidelines and manuals printed by associations such as OSHA, ACPA, NSCSA are available to build safety awareness for RMC producers^{8,13,14)}. These manuals and reports are also constituted upon European Commission (EC) directives and standards⁹⁾. A database that contains RMC incidents for further analysis is not available either due to the lack of academic studies. Therefore, it is not possible to perform studies to determine root causes of incidents occurring in RMC industry.

This study aims to fill this gap described above by conducting data mining in Turkish Social Security Institution

archives and performing univariate frequency and cross tabulation analysis on incidents that RMC truck drivers were involved. Also, seven ready mixed concrete plants in both Turkey and Netherlands were visited, interviews were conducted with the key personnel of these plants and each phase of the production was investigated with occupational safety point of view. Based on the results of this research, problem areas were determined and Job Safety Analyses were performed on these areas to suggest mitigation methods.

Methods

The methodology of this study consists of three major sections. The first section addresses the data acquisition process and how incident data pertaining RMC industry was obtained. The second section is the statistical analysis portion of the methodology and includes univariate and cross-tabulation analyses performed on the acquired data. The final section is dedicated to the Job Safety Analysis of selected activities typically performed by RMC truck drivers, which are based on the results of statistical analysis.

Data acquisition

Finding national work-related accident data is a serious challenge in Turkey. Social Security Institute (SSI) of Turkey publishes annual data on their website available for public access. However, it is not possible to obtain detailed data, specifically within the scope of one chosen industry. Therefore, database used in this study was obtained from SSI's archives located in Izmir, Istanbul and Ankara in Turkey with special permit to work in their offices. Since, the SSI archives contained all work-related injury reports in a single room regardless of industry or injury categorization system, datamining was performed among 2024 injury cases reported between 2010 and 2012. As a result of this study, 71 report forms related with RMC industry were handpicked and root causes of accidents determined from real cases. There have been no important changes during this period in compensation practices or in the way that accident data were collected and reported. Izmir, Istanbul and Ankara, as a most crowded three cities of Turkey, constitute 31% of general population¹⁵⁾. Physically, collecting data from all cities is not possible, so these three cities rapidly develop were focused for study.

A new taxonomy was created to rearrange and prepare the collected data for descriptive statistical analysis. A total of 15 research variables, which were grouped under three different categories according to their relevance to their

characteristics, were chosen for this study. These categories are time, accident, and worker characteristics.

Time characteristics variables were organized according to the injury occurrence date and included variables such as hour of the day, days of the week (including weekend) and months of the year.

Accident characteristics variables reveal plenty of information regarding the accident; in other words, they define the accident. Variables such as nature of injury, types of injury, damaged body part, source of injury (unsafe act or condition) were examined within the scope of the study. Tools/equipment being used during the injury was being selected as an additional category to obtain detailed information to determine risky operations.

Worker characteristics variables, addressing victim's personal information, were listed under this group. Workers' age group, worker's task and responsibility, educational background, and duration of work experience are variables that described workers' profile.

Univariate analysis

Univariate analysis is the simplest form of statistical analysis which includes describing a case in terms of a single variable; specifically, the distribution of the levels that compose it¹⁶⁾. Babbie in his book also mentions that primary purpose of univariate analysis is descriptive where multivariate analysis is geared more towards explanatory purposes. In other words, it explains data and tells the researcher what he/she has in hand¹⁷⁾. In vast majority of the construction safety literature the findings are based on univariate analysis and aimed at shedding light on problematic areas in this field, especially for accident causation^{18–20)}. In this research, univariate analysis was adopted for frequency analysis. The aim of the analysis was not only for data screening purposes; but also for understanding what we have and choosing the right variables for explanatory data analysis. Frequency tables were utilized for reporting findings of univariate analysis for total of 15 variables in this paper. Statistical Package for Social Sciences (SPSS) software was used for univariate analyses.

Cross-tabulation analysis

After conducting the univariate analysis, cross tabulation analysis was carried out to investigate whether a significant relationship between pairs of variables existed. Cross tabulation analysis produces a contingency table displaying the relationship, in the form of joint frequencies, of two or more variables. The rows indicating one variable while the columns indicating the other.

Determination of whether the relationship variables are statistically independent the joint frequency distribution can be analyzed by the Pearson chi-square statistic. Pearson chi-square compares the observed counts with those that would be expected if there were no association between two variables³⁵.

Pearson chi-square tests the hypothesis whether the row and column variables are independent or dependent. For this research study, the null hypothesis (H_0 and H_1) that formulated was;

H_0 = There is no association between the variable and degree of injury

H_1 = There is an association between the variable and degree of injury

The p -value is the probability value that is used for hypothesis testing by the Pearson chi-square test. After finding the p -value, one can decide whether the result is significant or not (commonly taken as 0.05). Therefore, a p -value less than 0.05 is accepted as significant and allows researcher to reject the null hypothesis (H_0) of no association, and conclude that there is an association between variables¹⁷.

If the null hypothesis is rejected, the next step is to determine the strength of this relationship. Phi (Φ) or Cramer's V (crv) values are used to evaluate the strength of association between the variables. Phi is a chi-square-based measure of association that involves dividing the Pearson (X^2) chi-square value by the sample size (N) and taking the square root of the result. Phi value can be calculated for only 2x2 contingency tables while Cramer's V value can be calculated for tables with more than 2x2 rows and columns. Phi or Cramer's values from 0 to 0.1 show a weak relationship; from 0.1 to 0.3 indicate a moderate relationship; and values between 0.3 and 1.0 suggest a strong relationship²¹. Due to symmetry, negative values of Φ are viewed to be the same as positive values. In this research, cross tabulation analysis was performed to determine statistical relationship and its strength between types of injury and other nominal variables. Results of cross tabulation analysis were presented using tables. Statistical Package for Social Sciences (SPSS) software was used for both univariate and bivariate statistical analyses.

Job safety analysis

Job safety analysis (JSA), which focuses on the interrelation among worker, task, tool and workplace environment, aims to define the hazards at each work item before their occurrence and produces solutions to completely eliminate the risks or to reduce the risks to acceptable levels²². The

ideal is to sub-classify the work after defining uncontrollable hazards in order to completely eliminate these hazards or to reduce their risks to acceptable levels²³. JSA might be adapted to almost all occupational groups. However, the branches of industry in which repeated processes are dominant are better being chosen in order to obtain economical and effective outputs²⁴. The most important advantage of this method is the fact that the method is not entirely based on personal assessments and the hazard analysis is performed simultaneously with the work itself²⁵.

JSA, in this study, was performed based on findings coming from statistical analysis and site visits conducted at seven different RMC plants located in Turkey and Netherlands. The analysis was divided into two sections: "Production area" and "casting site", and two different JSA forms were created accordingly, since, the processes are largely different from each other due to their nature. First column (operation) of the forms lists typical activities that workers engage in, either at production area or casting site. Variables used in "Responsibility" category were the primary source to determine typical activities. All possible hazards that workers could be exposed to during these operations are listed in the second column (hazard). Hazard related information was primarily obtained from observations and interviews with the key personnel of visited plants. In addition univariate analysis results were taken into consideration. Variables used in "Type of injury" category were integrated at this stage such as; falls, struck by falling objects, road accidents etc. Finally, third column (safety measure) on the forms suggested solutions for safety problems. Safety measures were mostly based on the information obtained from site visits to RMC plants. During these visits, safety managers and personnel were interviewed to understand proper safety measures. While some of these recommended measures were already in place, some did not exist due to budget restrictions. Also, observing the operations while they were being conducted and interviewing with the workers who performed the job played key roles to come up with some of the safety measures. In addition, searching the safety literature to find best practices helped supporting the suggested measures.

Results of Statistical Analysis

As addressed above, statistical analysis of the study focused on 71 work-related injury cases that occurred in three major cities (Izmir, Ankara and Istanbul) of Turkey. Findings of the analyses are summarized below:

Time characteristics (work hour, day and month) on

Table 3. Time characteristics of RMC Industry Work-Related Accidents

Hour of injury	No. of injury	% of injury	Month of injury	No. of injury	% of injury
12.01 – 16.00	19	26.8	January	12	16.9
08.00 – 12.00	17	23.9	October	9	12.7
16.01 – 20.00	17	23.9	March	9	12.7
20.01 – 24.00	8	11.3	December	9	12.7
Unknown	6	8.5	February	7	9.9
24.01 – 08.00	4	5.6	June	6	8.5
Day of injury	No. of injury	% of injury	November	5	7.0
Monday	17	23.9	July	4	5.6
Thursday	17	23.9	May	4	5.6
Saturday	11	15.5	April	3	4.2
Tuesday	10	14.1	August	2	2.8
Sunday	7	9.9	September	1	1.4
Wednesday	5	7.0			
Friday	4	5.6			

Table 4. Accident characteristics of RMC Industry Work-Related Accidents

Nature of injury	No. of injury	% of injury	Damaged body part	No. of injury	% of injury
Superficial Injury/Open Wound	20	28.2	Upper Extremity	28	39.4
Bruises	9	12.7	Lower Extremity	16	22.5
Fractures	9	12.7	Head	14	19.7
Ache/Pain	8	11.3	Multi-Injury	7	9.9
Cut	7	9.9	Whole Body	3	4.2
Foreign Body In Eyes	7	9.9	Back	2	2.8
Sprain/Dislocation	4	5.6	Innards	1	1.4
Concussion/Internal Bleeding	3	4.2	Tools/Equipment	No. of injury	% of injury
Fatality	2	2.8	Building Material	25	35.2
Electric Shock	1	1.4	Truck Mixer	24	33.8
Thermal/Chemical Burns	1	1.4	Concrete Pump	7	9.9
Type of injury	No. of injury	% of injury	No Tool	6	8.5
Fall	22	31.0	Manuel/Auto Hand Tools	5	7.0
Struck By Falling Object	19	26.8	Production Line	4	5.6
Caught In Or Between Objects	12	16.9	Unsafe Act/Condition	No. of injury	% of injury
Foreign Object In Body	7	9.9	Loss of Balance	22	31.0
Road Accident	4	5.6	Uncontrolled Object Movement	15	21.1
Inj. Resulting From Body Strain	3	4.2	No PPE Usage	11	15.5
Bite/Sting/Scratch	2	2.8	Wrong Working Methods	10	14.1
NSD Heat Exposure	1	1.4	Defective Equipment In Use	4	5.6
Electrocution	1	1.4	Inappropriate Position For Task	3	4.2
			Unknown	3	4.2
			Insufficient Housekeeping Prog.	3	4.2

which the injury occurred are demonstrated in Table 3. It was observed that a larger proportion of the RMC industry workers' incidents occurred in the hours between 12:01 p.m. and 16:00 p.m. (26.8%). On Mondays and Thursdays, there was a slight increase in the number of injuries

(23.9%) as demonstrated in Table 3. Furthermore, the rate of work-related occupational injuries was high during weekends, being 15.5% on Saturdays and 9.9% on Sundays. It also was determined that 16.9% of workers having work-related occupational injuries had been working

Table 5. Worker Characteristics of RMC Industry Work-Related Accidents

Age groups	No. of injury	% of injury	Responsibility	No. of injury	% of injury
30–34	15	21.1	Maintenance/Repair	29	40.8
40–44	14	19.7	Mixer/Pump Cleaning	18	25.4
25–29	12	16.9	Control Of Mechanism	7	9.9
35–39	12	16.9	Concrete Casting	7	9.9
Unknown	6	8.5	Truck Mixer Traffic to Casting Site	7	9.9
19–24	5	7.0	Materials Carrying	2	2.8
45–49	4	5.6	Rest	1	1.4
50–54	3	4.2	Duration of work experience	No. of injury	% of injury
Educational background	No. of injury	% of injury	>24 Months	18	25.4
Elementary Education	25	35.2	3–6 Months	14	19.7
Unknown	18	25.4	31.D-3 Months	11	15.5
Post Primary Education	12	16.9	6–12 Months	10	14.1
Higher Education	9	12.7	12–24 Months	7	9.9
Lettered	4	5.6	Unknown	5	7.0
University	2	2.8	2–4 Weeks	3	4.2
Non Lettered	1	1.4	1. Week	2	2.8
Worker's task	No. of injury	% of injury	Beginning At Same Day	1	1.4
Truck Mixer Operator	32	45.1	Working Environment	No. of injury	% of injury
Manufacturing/Maintainer	22	31.0	Production Area	50	70.4
Pump Operator	17	23.9	Casting Site	15	21.1
Number of Workers	No. of injury	% of injury	Transportation	6	8.5
<50	34	47.9			
>50	32	45.1			
Unknown	5	7.0			

on January (Table 3-Time Characteristics of RMC Industry Work-Related Accidents).

The results of univariate analysis on accident characteristics are presented in Table 4. The evaluation of type of injuries in ready-mix concrete industry has revealed that in 22 cases (31.0%) falls, in 19 of cases (26.8%) struck by falling object, and in 12 cases (16.9%) caught in or between objects were the cause of accident. Most encountered nature of injury has been found to be superficial injury and open wound (28.2%). Upper extremity damage has caused 28 workers (39.4%) injury.

Tragically, in this study, it is determined that 15.5% of those who had occupational accidents did not use personal protective equipment, particularly workers who worked at high elevations. In addition, loss of balance has caused injuries to 22 workers (31.0%) (Table 4-Accidents Characteristics of RMC Industry Work-Related Accidents). The major tools that have caused the accident are and building materials (35.2%) and truck mixer (33.8%).

The age of injured workers has also been evaluated, and 21.1% of these workers belong to the age group of 30–34

as shown in Table 5. According to their task, the majority of victims (45.1%) was truck mixer operator and had elementary education as an educational background (35.2%). The most surprising record we have found was that 18 workers (25.4%) have injured after more than two years' experience they started to work. It is also ascertained distribution of the causes of injuries in various responsibilities in the ready-mix concrete industry. The data showed that workers who made maintenance and repair had a significant risk (40.8%) at ready-mix concrete industry. In addition, workers who cleaned the truck mixer were second risky group that have injured at ready-mix concrete industry with 25.4% proportion of injury. The majority of the injured workers (70.4%) in the ready-mix concrete industry had been worked at production area with less than 50 workers (47.9%) (Table 5-Worker Characteristics of RMC Industry Work-Related Accidents).

In the cross tabulation analysis section of the study, the relationship between types of injury and other nominal variables were investigated and each analysis was interpreted. Only four of the variables (Working environment,

Table 6. Contingency table–Types of Injury vs. nominal variables

Variables	Pearson's chi-square $X^2(df)$, probability (p)		Phi & Cramer's V (crv)	
Working Environment	$X^2(16)=33.970$	$p=0.005$	$crv(16)=0.692$	$p=0.005$
Tools	$X^2(40)=70.481$	$p=0.002$	$crv(40)=0.446$	$p=0.002$
Unsafe Act/condition	$X^2(56)=196.502$	$p=0.000$	$crv(56)=0.643$	$p=0.000$
Worker's Responsibility	$X^2(48)=75.633$	$p=0.005$	$crv(48)=0.421$	$p=0.005$

Table 7. Contingency table–Types of Injury and Working Environment

		Working Environment			Total
		Casting Site	Transportation	Production Area	
Type of Injury	Fall	4 (18.2%)	1 (4.5%)	17 (77.3%)	22 (100.0%)
	Struck By Falling Object	2 (10.5%)	1 (5.3%)	16 (84.2%)	19 (100.0%)
	Caught In Or Between Objects	4 (33.3%)	1 (8.3%)	7 (58.3%)	12 (100.0%)
	Foreign Object In Body	1 (14.3%)	0 (0.0%)	6 (85.7%)	7 (100.0%)
	Road Accident	1 (25.0%)	3 (75.0%)	0 (0.0%)	4 (100.0%)
	Inj. Resulting From Body Strain	1 (33.3%)	0 (0.0%)	2 (66.7%)	3 (100.0%)
	Bite/Sting/Scratch	1 (50.0%)	0 (0.0%)	1 (50.0%)	2 (100.0%)
	NSD Heat Exposure	0 (0.0%)	0 (0.0%)	1 (100.0%)	1 (100.0%)
	Electrocution	1 (100.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)
Total		15 (100.0%)	6 (8.5%)	50 (70.4%)	71 (100.0%)

Table 8. Contingency table–Types of Injury and Tools/Equipment

		Tools						Total
		No Tool	Building Material	Manuel/Auto Hand Tools	Truck Mixer	Production Line	Concrete Pump	
Type of Injury	Fall	5 (22.7%)	2 (9.1%)	0 (0.0%)	11 (50.0%)	1 (4.5%)	3 (13.6%)	22 (100.0%)
	Struck By Falling Object	0 (0.0%)	10 (52.6%)	3 (15.8%)	5 (26.3%)	0 (0.0%)	1 (5.3%)	19 (100.0%)
	Caught In Or Between Objects	0 (0.0%)	2 (16.7%)	1 (8.3%)	5 (41.7%)	2 (16.7%)	2 (16.7%)	12 (100.0%)
	Foreign Object In Body	0 (0.0%)	7 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (100.0%)
	Road Accident	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (75.0%)	0 (0.0%)	1 (25.0%)	4 (100.0%)
	Inj. Resulting From Body Strain	1 (33.3%)	1 (33.3%)	0 (0.0%)	0 (0.0%)	1 (33.3%)	0 (0.0%)	3 (100.0%)
	Bite/Sting/Scratch	0 (0.0%)	2 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (100.0%)
	NSD Heat Exposure	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)
	Electrocution	0 (0.0%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)
Total		6 (100.0%)	25 (100.0%)	5 (100.0%)	24 (100.0%)	4 (100%)	7 (100%)	71 (100.0%)

tools, unsafe act/condition and responsibility) were found statistically significant as shown in Table 6. According to results (Cramer's v) one can say types of injury had strong relationship with working environment, tools, unsafe act/condition and worker's responsibility. The second stage of cross tabulation analysis involved analyzing type of injury categories versus each statistically significant variable category. Thus, major factors and categories affecting the occurrence of accident were determined. The results of this stage are summarized below.

The cross tabulation analysis between working environment and types of injury showed that (Table 7), injury categories such as falls (77.3%), foreign object in body (85.7%)

and struck by falling object (84.2%) were observed mostly at RMC production area, while road accidents were mostly observed during transportation as expected (75%). In addition, 50% of bite/sting/scratch typed injuries occurred at casting site.

According to cross tabulation analysis between types of injury and tools, it was observed that 52.6% of struck by falling object injuries were caused by building materials as shown in Table 8. Truck mixers have caused 75% of road accidents, 50% of falls and 41.7% of caught in or between objects. Workers who worked close to production line got injured resulting from body strain (33.3%) and caught in or between objects (16.7%).

Table 9. Contingency table – Types of Injury and Unsafe Act/Condition

		Unsafe Act/Condition							Total
		Inapp. Position For Task	Wrong Working Methods	Insufficient Housekeeping Prog.	No PPE Usage	Loss of Balance	Defective Equipment In Use	Uncontro. Object Movement	
Type of Injury	Fall	0 (0.0%)	0 (0.0%)	1 (4.5%)	0 (0.0%)	21 (95.5%)	0 (0.0%)	0 (0.0%)	22 (100.0%)
	Struck By Falling Object	1 (5.3%)	1 (5.3%)	1 (5.3%)	2 (10.5%)	0 (0.0%)	1 (5.3%)	13 (68.4%)	19 (100.0%)
	Caught In Or Between Objects	0 (0.0%)	6 (50.0%)	1 (8.3%)	1 (8.3%)	0 (0.0%)	2 (16.7%)	2 (16.7%)	12 (100.0%)
	Foreign Object In Body	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	7 (100.0%)
	Road Accident	0 (0.0%)	1 (25.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (75.0%)
	Inj. Resulting From Body Strain	2 (66.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (33.3%)	0 (0.0%)	3 (100.0%)
	Bite/Sting/Scratch	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (50.0%)	1 (50.0%)	0 (0.0%)	0 (0.0%)	2 (100.0%)
	NSD Heat Exposure	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)
	Electrocution	0 (0.0%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)
Total		3 (100.0%)	9 (100.0%)	4 (100.0%)	11 (100.0%)	22 (100.0%)	4 (100.0%)	15 (100.0%)	3 (100.0%)

Table 10. Contingency table – Types of Injury and Responsibility

		Responsibility							Total
		Control Of Mechanism	Truck Mixer Traffic to Casting Site	Materials Carrying	Concrete Casting	Rest	Mixer/Pump Cleaning	Maintenance/Repair	
Type of Injury	Fall	4 (18.2%)	4 (18.2%)	0 (0.0%)	1 (4.5%)	1 (4.5%)	4 (18.2%)	8 (36.4%)	22 (100.0%)
	Struck By Falling Object	2 (10.5%)	0 (0.0%)	1 (5.3%)	0 (0.0%)	0 (0.0%)	6 (31.6%)	10 (52.6%)	19 (100.0%)
	Caught In Or Between Objects	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (16.7%)	0 (0.0%)	2 (16.7%)	8 (66.7%)	12 (100.0%)
	Foreign Object In Body	1 (14.3%)	0 (0.0%)	0 (0.0%)	1 (14.3%)	0 (0.0%)	5 (71.4%)	0 (0.0%)	7 (100.0%)
	Road Accident	0 (0.0%)	3 (75.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (25.0%)	4 (100.0%)
	Inj. Resulting From Body Strain	0 (0.0%)	0 (0.0%)	1 (33.3%)	1 (33.3%)	0 (0.0%)	0 (0.0%)	1 (33.3%)	3 (100.0%)
	Bite/Sting/Scratch	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (50.0%)	0 (0.0%)	1 (50.0%)	0 (0.0%)	2 (100.0%)
	NSD Heat Exposure	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)	1 (100.0%)
	Electrocution	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (100.0%)
Total		7 (100.0%)	7 (100.0%)	2 (100.0%)	7 (100.0%)	1 (100.0%)	18 (100.0%)	29 (100.0%)	71 (100.0%)

The cross tabulation analysis between types of injury and unsafe act/condition was also performed. It was observed that 66.7% of injuries caused by inappropriate position for task and 33.3% of injuries caused by defective equipment in use resulted with body strain. When fall injuries were examined from unsafe act/condition point of view, it was seen that nearly all of (95.5%) loss of balance injuries resulted in falls. At the same time, as an unsafe act/condition, wrong working methods (50%) was the major factor for caught in or between objects (Table 9).

The cross tabulation analysis between worker's responsibility and types of injury was performed as a final analysis (Table 10). The data showed that during the mixer/pump cleaning process foreign object in body (71.4%), bite/sting/scratch (50%) and struck by falling object (31.6%) were the three major types of injury. When maintenance/repair process was analyzed from type of injury point of view it is also observed that caught in or between objects (66.7%), struck by falling object (52.6%) and falls (36.4%) were the

three major categories.

Results of Job Safety Analysis

JSA performed in this study generated two different forms that display potential hazards and their corresponding safety measures. Results of JSA pertaining operations at production area and casting site can be seen in Table 11 and Table 12 respectively.

It was observed that fall from elevated heights is an immediate hazard that needs to be dealt with in both production and casting process. Environmental hazards such as dust and noise is present in both processes with varying degrees of exposure. It was also determined that ergonomic risks during material handling, transportation and casting threaten workers' health.

JSA tables revealed that mitigation methods exist for nearly all of the hazards, as long as the resources are allocated. Statistical analysis revealed that cleaning of truck

Table 11. JSA of Operations at Production Area

Operation	Hazard	Safety Measure
Control/maintenance/repair -Aggregate belt conveyors and feeders	Trapping between conveyor belts in motion and head/tail drums	Tail and head drums, moving parts should be protected
		Warning signs to prohibit working on belts in motion should be installed
		Single switch operation of belts and conveyors should be enabled
		Emergency stop lines should be designed along length of conveyor belts
	Falling from upper parts of belt	All staff should be trained in the isolation procedure which must be implemented before any guards or protection is removed
		Walkways should be designed by grooved or perforated anti-slip floors
		Safety handrails along all walkways should be designed
	Falling object	Usage of firmly attached safety belts during maintenance should be controlled
		Trays/pans should be used to catch material falling from belts,
	Falls into hopper	Protective covers on undersides of conveyor belts should be supplied
Mixer/pump cleaning -Worker climbs to the top of truck mixer to clean up	Falls from the top of mixer	Design barriers around grid and hoppers or grille over hoppers should be designed
		Production of dust
		Protective covering should be supplied to conveyors to minimize dust
		Safe access platform in mixing area should be used
		Warning signs to draw attention of drivers if slippery surfaces on site cannot be eliminated
		Truck drivers should be informed about ergonomic risk factors
Mixer/pump cleaning -Worker gets inside truck mixer drum to clean debris and remove hardened concrete	Working at confined spaces and exposure to silica dust while removing hardened concrete inside the drum	Ladders on truck mixers should be inspected for defects before every usage
		Wet methods should be used during mixer drum cleaning
		Ventilation should be used during mixer drum cleaning
		Usage of water spray attachments for chipping tools and wetting procedures should be supplied and ensured
		All activities staged inside mixer drums should be done with pneumatic chipping tools.
		Supplement engineering and work practice controls with respirators should be supplied
	Chemical burns from cleaning operations.	Guard against heat stress when cleaning truck mixer drums should be supplied with air conditioning
		Drivers should wear respiratory mask to avoid silica exposure when removing concrete residues from inside truck mixer drums
		Drivers should be trained to avoid direct contact with concrete during the removal of hardened concrete process and correct operation of truck mixers including maintenance and cleaning
	Trapping, amputations by mixing mechanism	Protective clothing should be used for hands, eyes, ears, head during cleaning
		Implement programs for machine guarding and lockout/tag out should be designed
		All moving parts should be covered by protection covers

mixers is a hazardous activity and source of many injuries. Therefore, installing guardrails against falls, using wet methods, ventilation and personal protective equipment where needed could prevent illnesses and injuries.

Discussions and Conclusion

Ready mix concrete, as shown in table 1, is rapidly developing in many countries while it is hard to find scientific accident database and academic studies related with

Table 12. JSA of Operations at Casting Site

Operation	Hazard	Safety Measure
Transportation	Traffic Accidents	Truck mixer drivers should observe traffic rules when driving on road
	Noise	Truck mixer drivers should be suggested listening to low tone music in the trucks in-stead of high tone
		Noise sources in the trucks should be reduced by installing noise transmission barriers and using preventive maintenance
	Ergonomic risk factors	Install equipment that helps drivers minimize twisting and turning while in the cab
		Whole-body vibration in truck cabs should be reduced by methods such as isolating cab from vibrations, using air-ride suspended seats, and using adjustable, well-padded seats and backrests
		Arrange implementation of frequent (hourly) rest breaks for drivers exposed to extensive whole-body vibration
		Train the truck drivers to avoid awkward and fixed postures
Slump checking and adding water or admixtures to the mix	Extremes of temperature	Air conditioner should be used
	Falling Falls from the top of mixer during	A guard at the top opening of the mixer drum can protect drivers from falling into drums during checking slump
Concrete casting	Noise	Provide flat attenuation hearing protection devices and control the usage of them (PPE)
		Repeat sound-level measurements and audiometric testing
	Falling while climbing and descending truck cab and equipment	To eliminate the need to climb onto trucks and to minimize ladder use reconfiguration of water tanks and other truck equipment should be planned
		At the top opening of the mixer drum a protective guard should be installed
		To enable drivers to reach the upper parts of trucks during washing and inspection activities elevated platform with stairways and guardrails should be installed
		Drivers should be informed about ergonomic risks
		Inspect the ladders on truck mixers for defects before every usage
	Skin contact with concrete and admixtures, which may contain irritant and sensitizing materials	Implement a system that deals with selection and distribution of gloves and training of workers on proper usage of gloves during the discharge process.
		Instruct the truck drivers on personal hygiene particularly after the discharge process
	Eye Injuries	Implement PPE usage for eye protection.
	Extremes of temperature	Regulate the truck drivers' daily work schedule considering their previous shifts
	Rollovers while driving and unloading on unstable, uneven or steep ground at delivery sites	Train the operators not to start the discharging operation until safely park position of the truck has been secured
	Ergonomic Risk Factors	Train the truck drivers to avoid awkward and fixed postures
		Safety locks should be used on mixer operation
		Warning signs for not to work on mixers in motion should be used
		On access hatches automatic mixer stop catches should be used
		Security grids on observation windows to prevent access
		All moving parts should be covered by protection covers

potential hazards of industry in Turkey or in other countries. This study aimed to fulfill this gap and raise awareness.

Following findings were detected based on statistical analyses of 71 cases:

- Generally, construction sites are known as one of the most dangerous working areas because of its dynamic, changeable nature and complex tasks. On the other hand RMC production areas are more systematic, repetitive and ordinate. However, surprisingly statistical analysis showed that 7 out of 10 RMC related accidents occurred at production area, while only 3 out of 10 occurred at casting sites.
- However, the group with a considerable risk level is truck mixer operators. According to analysis it is determined that 45.1% of the victims were truck mixer operators. Truck mixer operators mostly got injured when they clean mixer/pump (37.5%) followed by transportation for concrete casting (18.8%) and maintenance/repair (18.8%). This result shows that operators are mostly under risk when they come back from casting to clean their truck mixers at production sites.
- The evaluation of type of injuries in ready-mix concrete industry has revealed that in 22 cases (31.0%) falls, in 19 cases (26.8%) struck by falling object, and in 12 cases (16.9%) caught in or between objects were the cause of accident. Fall has been reported as the leading cause of accidents in construction industry (range from 22 to 33%) by many researchers^{19, 27–29}. RMC industry shows similarity with construction sector when findings related with falls compared. However, struck by falling object category is frequently monitored at RMC industry. According to statistics reported by Indiana Department of Labor the three major types of injuries at ready-mixed concrete industry are falls, road accidents and struck by falling objects³⁰. This result also complies with the findings of Arndt *et al.*, who also found that one of the common causes of fatal injuries in the construction industry is struck by falling objects³¹.
- Most encountered nature of injury has been found to be superficial injury and open wound (28.2%). Upper extremity damage has caused 28 workers (39.4%) injury. According to statistical findings reported by The Nova Scotia Construction Safety Association (NSCSA), the most frequently injured body part is back part of body (30.8%). Following part is legs with 19.5% and arms with 7.5%¹⁴. Within the scope of another report it is pointed that the most frequently

injured body part is upper extremities³⁰.

- It was found that compared to the rest of the weekdays there were more accidents occurring on Monday and Thursday. Kazan¹⁷ and Akboğa&Baradan²⁶ found the same results on their studies.
- Various studies showed that workers with less work experience, particularly within the first month of employment, are more prone to injuries^{26, 32, 33}. However, most surprisingly, findings of statistical analysis showed just the opposite. Working for many years at same company could be the reason of getting used to risks. Repeating safety training regularly could solve this problem.

Job Safety Analysis should not be performed based solely on site observations. Case histories (statistics of accidents records) should also be taken into consideration. JSA would be more realistic with the support of statistical analysis findings. JSA forms shall be ordered chronologically, the hazards for each step shall be defined, the methods for preventing/eliminating the hazard shall be defined, and required PPE shall be provided whenever there is a need. Hazard Identification and Control is the largest element in a company's safety program. When completed thoroughly, it will be used as the foundation for all other areas of the program.

It is expected from the RMC producers to create an occupational safety and health department with a focus on training. It is best to determine training topics and contents based on JSA results and company based statistical database. JSA forms presented in this study could also be helpful for companies who want to establish a safety and health program.

The essential deficiency in the RMC industry is that the occupational injuries and illnesses are not recorded systematically, thus the potential of occupational accidents are neglected. Collecting statistics on safety activities will allow a company to identify common injuries and areas that may be lacking in their safety program.

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