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Postural Evaluation and Virtually Designed Bin Table for Collection and Eviction of Slab Concrete Mix at Construction Work

Manoj T. Gajbhiye[1], Suman Das[2], Debamalya Banerjee[3], Saurav Nandi[4]

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ABSTRACT

Slab-concreting is one of the important tasks in construction in which structural element exercises to generate horizontal flat surface at the roof or ceilings. The study was conducted to evaluate the working postures of 68 laborers performing concrete mix laying on the floor for slab concreting. The ERIN, RULA and REBA methods were used to evaluate workers' real-time work patterns followed by design of collection and discharging tables designed and modelled. Biomechanical and lifting/lowering analysis were performed on the manikin while working on the newly developed table. Results indicate that laborers are working in vulnerable condition with extremely high ergonomic risk and exposing to work-related musculoskeletal disorders. The most exposed parts of the body are the Lower back (85.29%), shoulders (66.18%), arms/hand (48.53%). Newly proposed collecting and Eviction bin table minimizes the risk of work-related musculoskeletal disorder on the different parts of the body.

Keywords: Postural evaluation; Slab-concrete; ERIN; RULA; REBA.

INTRODUCTION

Work-related musculoskeletal disorders are the major component of job-related illness in the workplace which occurs due different ergonomic risk factor. These are caused by working in awkward position, work repetitively, heavy lifting/lowering, prolong working in static and dynamic postures, undue pressure on lower back, gravity force on body parts etc. Unskilled workers in the construction work; the so called laborers or coolies work very hard at construction sites. They are involved in physically demanding work where they are perform lifting, lowering, carrying construction materials and moving materials from one place to another place for smooth running of various construction works. At the same time they are also perform different construction related activities like excavation, surface or area cleaning, mixing of mortar and concrete mixture, supply of construction materials etc. Slab concreting is one of the major tasks to be carried out in the construction work. This slab concreting carried out at floor as well as for roof. This is the general structural element of the house or any building that use to

Author Affiliation: [1]Research Scholar, Department of Production Engineering, [3]Professor, Department of Production Engineering, Jadavpur University, Kolkata-700032, West Bengal, India, [2]Professor, Department of Mechanical Engineering, Swami Vivekananda Institute of Science & Technology, Kolkata-700145, West Bengal, India, [4]Assistant Professor, Department of Mechanical Engineering, Calcutta Institute of Engineering and Management, Kolkata-700040, West Bengal, India.

Corresponding Author: Suman Das, Professor, Department of Mechanical Engineering, Swami Vivekananda Institute of Science & Technology, Kolkata-700145, West Bengal, India.

E-mail: sd_suman@yahoo.co.in

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develop flat horizontal surface at floor, roof decks and at ceilings. The floor concrete provides plain horizontal surface at base and the roof or ceiling concrete serve as a protection and covering to the house or building and also insulate house from sound, heat, fire, cold etc. Slab concreting is layer of molded plain or reinforced concrete, flat horizontal and uniformly distributed which is supported by beams, columns, walls and other framework and on the ground also. This is in general several millimeters thick and supported by beams, walls, floor surface and columns. The concrete mixture composition that uses four major elements like gravels, sand, cement, water mixed in a required ratio. In India, slab concreting is done manually. Concrete mixes are traditionally made and transported by hand but currently concrete mixers machines are used concrete mixing as well as lift/elevator are used for concrete mix transportation. Though the mixing of the concrete perform using concrete mixture machine and lifted to the desired height using lift, some work is carry out manually. This work is to transfer the concrete mixture to the desired location for the formwork from depository location. The concrete mixtures get collected at one of the space on the formwork or roof with the help of lift. The hopper unloads the concrete mix on the floor and then transported to the desired location for laying with the help of laborers.

Laborers collect the mixture in the head-pan, lift the head-pan and transported the mixture. For this work laborer have to bend forward to collect and lift the head-pan. The average weight of the head-pan with the mixture is 20kg. This transporting of concrete mix is found to be hazardous which was found to be overwhelming, forceful, repetitive, over exertional in nature as well as laborers found working in awkward posture. Working in such awkward posture and frequent bending, forceful and heavy lifting weights is hazardous work which leads to the development of work-related musculoskeletal disorder. The type of work a cause back and shoulder injuries and is associated with vertebral disorder and has a depressing effect on individual labor and society and impairs the health of workers.[1] Many researcher performed risk assessment of working posture on various construction works and other areas[2-7] as investigation of such risk factors and it intensity is the crucial step that can minimise the problem of work related musculoskeletal disorders. Sensors based risk assessments have also been performed to evaluated ergonomics risk for different task and conditions.[8-13] Despite such studies, there has been a limited focus and efforts in India on unskilled workers such as laborers, helpers or coolies. According to Hoonemans et at. (2008), height and weight lifting play a significant role in contributing to low back disorder. Therefore, the vertical position of the object to be lifted should be in the range of 320mm to 1550mm for manual material handling. At the same time weight of the object to be lifted should be in the range of 7.5-15kg.[14] Therefore, the objective of this study is to (1) identify the hazard factors of slab, body parts, lifting height, weight lifting and other related parameters with the laborers involved in the work of slab- concreting and (2) to propose some design/structures which can be used to collect and lift concrete mixture to the permissible height and weight lifted.

MATERIALS AND METHODS

A four-week study was conducted to study the work of slab concreting work at various construction sites. Eight different construction sites were visited and a total 68 laborers were observed, video recorded and interviewed. Only male laborers were employed for this work. The Table 1 shows the background characteristics of the laborers. The standard weighing machine and measuring steel tape were used to measure the height and weight of the laborers as well as height of elevator and weight of filled head-pan. The individual data like age, working experience, daily working hours, pain in the body parts, history of traumatic incidents, feeling discomfort, addiction to alcohol/smoking/tobacco were asked using simple questionnaire. The ERIN, RULA and REBA method were used to evaluate the ergonomic risk of selected postures of laborers. Computer manikin was developed in the CATIA software for model designing, biomechanical analysis and lifting analysis. Laborers between the ages of 26 to 59 were found to have 3 to 36 years of experience. Statistics show that 44 laborers migrated from the other state. Out of 68 laborers 6 were illiterate, 38 laborers have completed primary education, 19 laborers have completed secondary education and 5 laborers have completed intermediate education.

When laying slab concrete, the laborers have to perform four task i.e. (1) Collecting slab-concrete mixture in the head-pan, (2) lifting of Head-pan and (3) laying the slab-concrete mixture in the desired place on the formwork/centering. While performing these tasks, the laborers have to bend forward (flexion posture at lumbar), work in the extended posture and awkward posture. While lifting the Iron-pan, the laborers have to work hard to lift the head-pan. A laborer engaged in performing the task of unlocking and locking the hopper in the elevator to release the slab concrete on the slab floor as shown in fig. 7 (a), (b) and (c).

Gajbhiye et al.,(2021) working in such posture is dangerous and injurious to health and keep compression load on L4/L5 which exceeds the recommended limit of NIOSH.[15] Then all laborers used to perform above mentioned task. Real time postures are evaluated using ERIN, RULA and REBA methods. Manikin and the proposed table model were developed in CATIA and biomechanical, lowering and lifting analysis was performed on manikin using the proposed model for lifting different weights. Using the new proposed table, the results of 10kg, 12kg, 15kg and 20kg weight lifting were calculated using CATIA. To develop a computer manikin to evaluate the posture, repetition, static muscle load, force, working postures and break time are not considered. The standard rule of anthropometry is set as according to rules. The colors green, yellow, orange and red are designated for "No risk posture", "Medium Risk Posture", "High Risk Posture" and "Very high risk postures " respectively.[16]

RESULTS

General Information

The studied laborers are engaged in collecting and discharging concrete on the slab form work. Table 1 shows the somatic characteristics data of the worker. The duration of working hours depends on the need of the work but usually these laborers are engaged in slab concreting work for 6 to 7 hours depending on the height of the slab to be completed by the concrete from the ground and the total area of the slab. Average BMI was found to be well under control however 9 laborers BMI were found to be above the BMI control limit. The average weight of the head-pan with concrete was found to be 21.55 kg and the average lifting time was 180 seconds per lift.

Musculoskeletal disorders complaints by the laborers

The response to the pain in the body parts and its percentage is shown in the Table 2, figure 1 and figure 2. Table 2 shows that laborers suffer from lower back pain (85.29%), shoulders (66.18%), arms/hand (48.53%), chest (20.59%), knees (16.18%), ankle/feet/toe (11.76%), Neck (10.29%), head (7.35%), fingers/thumbs (7.35%) and legs (7.35%) and wrist (5.88%). According to the survey, it is revealed that 86.76 % laborers working in awkward posture, 36.76% laborers have pain after working, 30.88% laborers have pain in the morning, 13.24 % laborers during working while 10.29% of the laborers pain during sleeping. Figure 2 shows that 30%, 23%, 17% and 6% laborers have pain in lower back, shoulder, Arms/hand and fingers/ Thumbs.

Present setup of concrete elevator and working postures of laborers

Figure 5 and Figure 6 show the actual setup of concrete casting. In concrete casting, a concrete mixing machine equipped with an elevator uses to supply the concrete mix up to the slab (formwork) at desired height. The mixture is placed on the ground level and concrete mixture is transported by means of an elevator equipped with hopper. Concrete is deposited on the temporary foundation made up of form plates (Figure 5). Approximately 2400 mm × 2400 mm space is used to the collect the concrete mix on the floor of roof formwork on the ceiling. The hopper stops at a height of 900mm from the base and drops the material on the floor from where laborers collect it. The total height of the elevator is maintained at about 3000-3300mm from the base of the formwork. (Figure 5). Figure 6 shows how the concrete mix is being collected on the floor and in figure 7 the laborers are collecting concrete mix in an iron-pan. Figure 7 clearly shows that all the laborers are working in forward bending posture. Also in the figure 4 (a)-(c), the labor is unlocking the hopper from the elevator and while performing this task, the labor appears to be working in unsafe posture and condition.

Results obtained by using ERIN, NERPA and WERA methods

ERIN, RULA and REBA methods have shown that all postures performing collecting concrete in an iron-pan and lifting a concrete mixture iron-pan is at very high risk and immediate action is required to minimize the further destruction. From the ERIN method; it is also revealed that all postures are at very high risk as the score obtained for postures are more than 35. The RULA method score for all posture found to be more than 7 which indicate that they need immediate action. REBA's final score indicates that the score obtained for all the postures are above 11, which indicates that all the assessed posture are at very high risk. The results of all the methods applied for the assessment of all the working postures of the laborers engaged in the work of slab-concreting are at very high ergonomic risk and immediate remedial action is required. The analysis also found that lower back and shoulders were at very high ergonomic risk, and workers reported the same in their interviews.

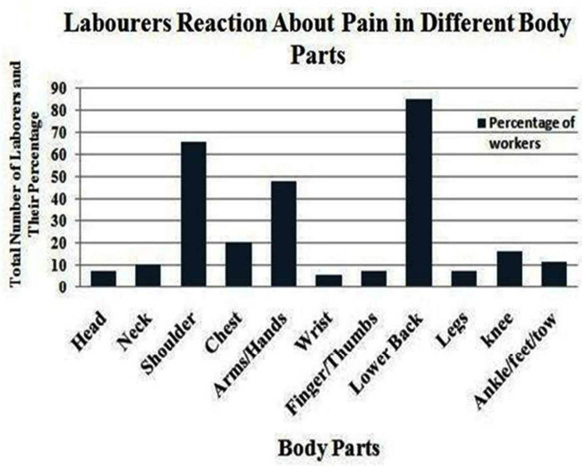


Fig. 1: Labourers Reaction about Pain in Different Body Parts

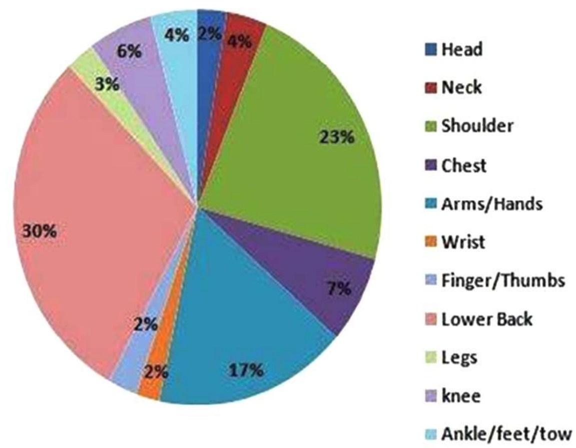


Fig. 2: Percentage of Laborers having Pain in Different Body Parts

Fig. 3: Figure of real time elevator with vertical distance.

Fig. 4: Figure of real time elevator with hopper releasing concrete on floor

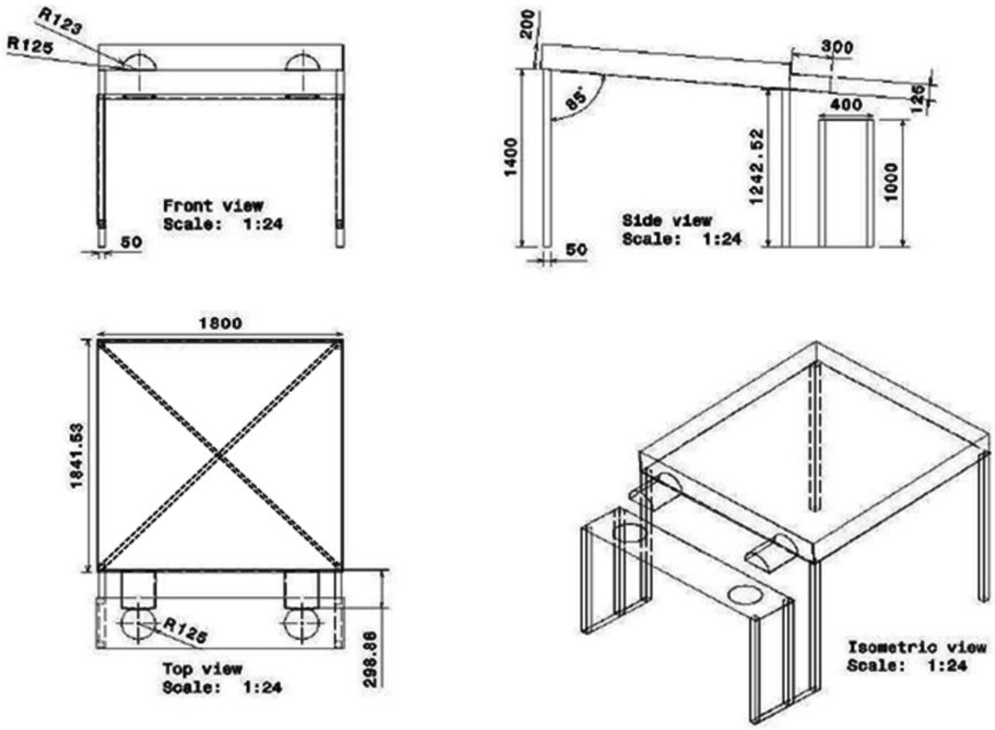
Fig. 5: Laborers collecting concrete in the iron-pan

Fig. 6: (a): Collection of Concrete in the head-pan POSTURE-1

Fig. 6: (b): Lifting of Head-Pan POSTURE-2

Fig. 6: (c): Lifting and holding Head-Pan on head POSTURE-3

Fig. 7: (a) (b) and (c) Unlocking and locking of Hopper (POSTURE-4)



All measurement are in mm

Fig. 8: Proposed Table for collecting and releasing concrete

Fig. (a): Height of stand 1000mm

Fig. (b): Height of stand 500mm

Fig. 9: Different size of stands for lifting of Head pan

Fig. 10: RULA Score **Fig.** (a): RULA Scores for left side of the manikin

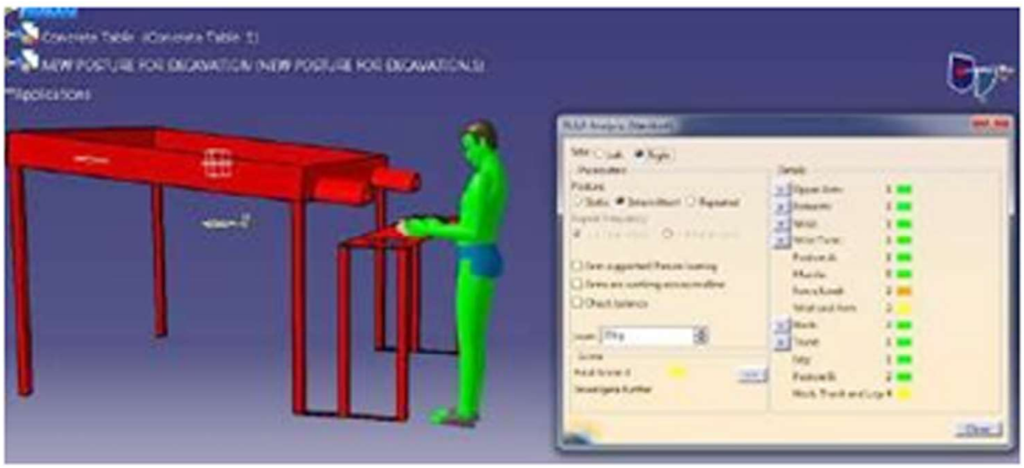


Fig. 10: RULA Score **Fig.** (b): RULA Scores for right side of the manikin

Fig. (a): Biomechanical analysis score for 10 kg

Fig. 11: Biomechanical Analysis for different weight

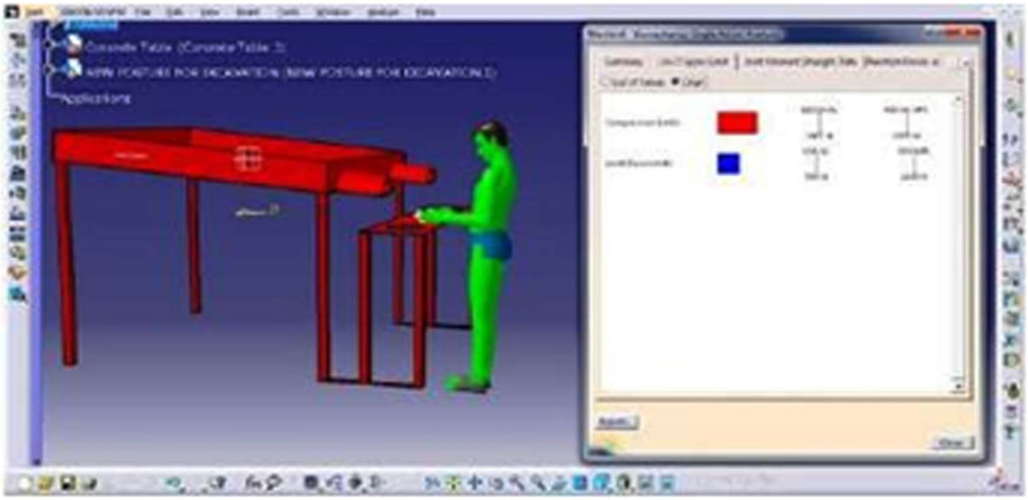


Fig. (b): Biomechanical analysis score for 12 kg

Fig. 11: Biomechanical Analysis for different weight

Fig. (c): Biomechanical analysis score for 15 kg

Fig. 11: Biomechanical Analysis for different weight

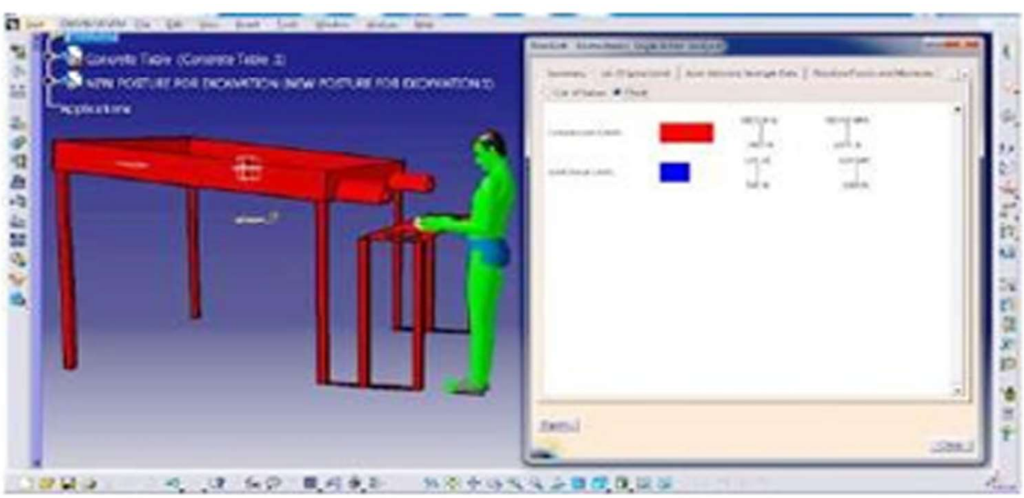
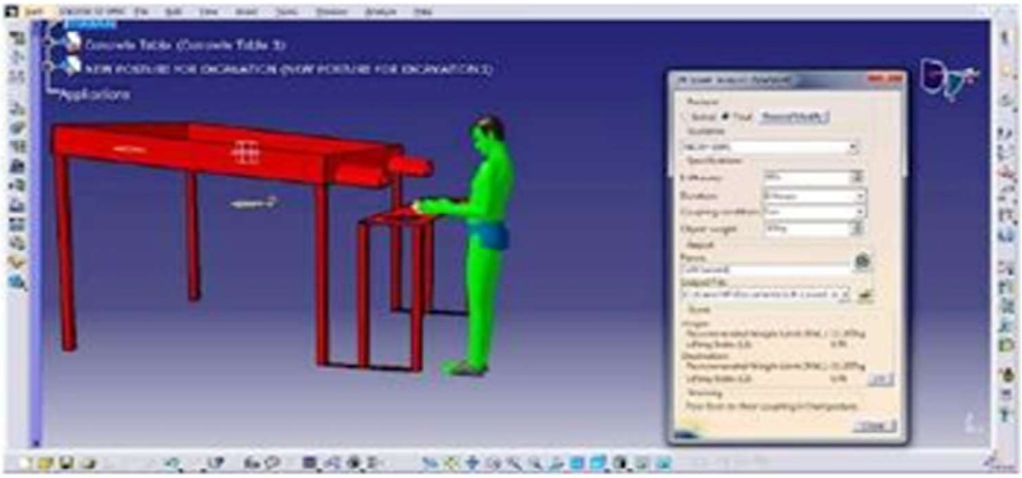


Fig. (d): Biomechanical analysis score for 20 kg

Fig. 11: Biomechanical Analysis for different weight

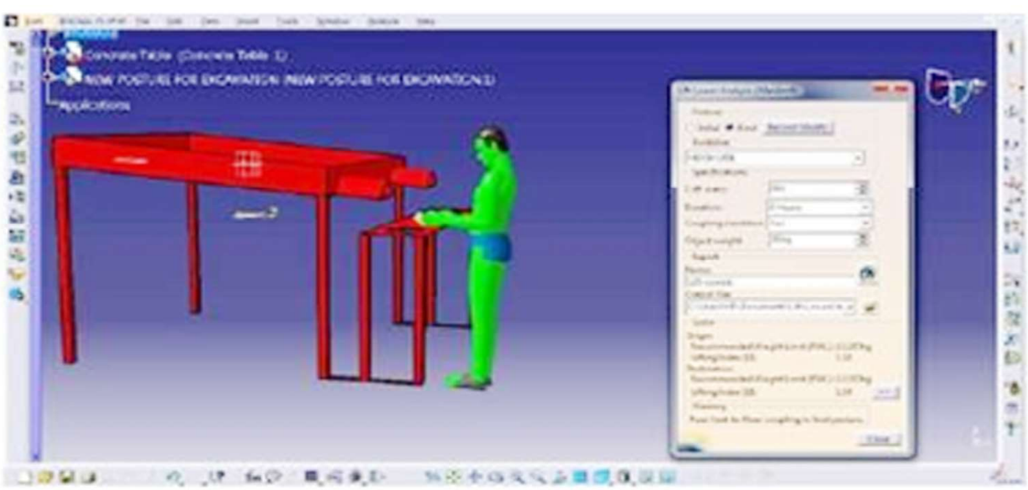


(a) NIOSH Lifting analysis score for 10 kg

Fig. 12: Lifting analysis scores for different weight

(b) NIOSH Lifting analysis score for 12 kg

Fig. 12: Lifting analysis scores for different weight



(c) NIOSH Lifting analysis score for 15 kg

Fig. 12: Lifting analysis scores for different weight

(d) NIOSH Lifting analysis score for 20 kg

Fig. 12: Lifting analysis scores for different weight

Design of Concrete Collection and Discharging Table

The new collection and eviction table was designed and modeled in CATIA software. Figure 8 shows a detailed drawing of the collection and eviction table. After the table was designed, manikin were modeled and analysed for table designed using various parameters for collection and lifting of the iron-pan. The ERIN and REBA worksheet and CATIA's RULA method were used to evaluate manikin postures. CATIA performed biomechanical and lifting analysis for different weights such as 10kg, 12kg, 15kg and 20kg in the CATIA. The materials proposed for the table is M. S. Sheet of MS 5.31 mm (5 gauge), M.S. Angle of size (25 mm × 25 mm × 5mm) and Pipes size Square Pipe (50 mm x 50 mm x 2 mm). The height of the table is 1400 mm on the elevator side and 1250mm on the discharge side. The inclination of 150 is placed towards the discharge area. The size of the collection bin is 1800x1800x200mm and there are two openings on the discharge side. The MS angles were used on all four sides and in the center diagonally to support the storage bin on the base. The MS angle use for support the storage bin of the table at the four sides and in the diagonal at the base of the bin. Since the height of the storage bin was 200mm, the total height of table increased to 1600mm. The height of the table used for holding iron-pan is 1000mm and width is 400mm which is attached to the discharge side of the table as shown in figure. The upper side of this attached table is equipped with two round opening for proper base for iron-pan holding just below the discharge opening.

The height of the table used to hold the iron-pan is such that the iron-pan can be comfortably placed and lifted. From this study, it has been shown that the comfortable height/space for lifting any material is between 900-1100 mm. For this, an experiment has been performed to find the comfortable height of the head-pan to be lifted. Stands of 1000mm and 500mm height were constructed and experiments were carried out for height validation. (Fig. 9 (a) and Fig. 9(b) and Fig. 3(b)). Experimental results showed that when the head-pan was lifted from the ground level and from the 500mm above the ground level, the laborers had to bend more to lift the head-pan and at the same time they had to put more effort to lift the head-pan. But when the head-pan was lifted from the height of 1000mm above the ground, it became more convenient to lift and require less effort. This has been reported by other researchers with some variation.[14,17] Therefore, the height of the table for collecting concrete mix was kept at a height of 1000mm. When deploying new table, the height of the lift must be increased by 1600-1800 mm as required. It is necessary to increase the height of the elevator by 1600-1800mm as required. In such cases, the total height of the lift will have to be increased from 3000mm to 4800mm as per requirement. The scaffolding must be arranged at the desired height on the left side of the elevator for the worker involved in unlocking and locking the hopper from the elevator to stand.

Table 1: Somatic Characteristics of workers (N=68)

Characters	Mean (±SD)
Age (years)	42.49 (± 9.03)
Height (cm)	163.47 (± 4.70)
Weight (kg)	61.82 (± 5.64)
Work Experience (years)	18.15 (± 8.15)
BMI (kg/m2)	23.14 (± 1.90)
Working hours/day (hours)	6 (±1)
Rest hours/day (hours)	0 (± 30min)

Table 2: Laborers' reaction about pain/discomfort in body

Body Parts	No. of workers having pain in different body parts	Percentage of workers
Head	5	7.35
Neck	7	10.29
Shoulder	45	66.18
Chest	14	20.59
Arms/Hands	33	48.53
Wrist	4	5.88
Finger/Thumb	5	7.35
Lower Back	58	85.29
Legs	5	7.35
knee	11	16.18
Ankle/feet/toe	8	11.76
Working in Awkward	59	86.76

Table 3: Laborers' reaction about pain/discomfort in different time zone

Parameters	No. of workers having pain in different body parts	Percentage of workers
During Working	9	13.24
After Working	25	36.76
during sleeping	7	10.29
In the morning	21	30.88

Table 4: Score for all postures

BP	P1	P2	P3	P4		
				(A)	(B)	(C)
BK/T	8	8	8	8	8	8
S/UA/LA	5	6	9	9	9	9
H/W	5	5	5	5	5	5
N	7	6	6	3	3	3
R	6	6	6	6	6	6
IOE	8	8	8	7	7	7
SA	3	4	3	2	2	2

BP	P1	P2	P3	P4		
				(A)	(B)	(C)
UA	3	4	4	4	4	4
LA	2	3	3	3	3	3
W	3	4	3	3	3	3
WT	1	1	1	1	1	1
SC (A)	4	6	5	5	5	5
M	1	1	1	1	1	1
F	2	3	3	3	3	3

BP	P1	P2	P3	P4		
				(A)	(B)	(C)
N	3	3	3	3	3	3
BK/T	4	4	4	3	3	4
L	3	22	3	3	3	3
PS-A	8	7	8	7	7	8
F	1	2	2	2	2	2
TS-A	9	9	10	9	9	10
UA	3	4	5	5	5	5

							SC (C)	7	10	9	9	9	9	LA	1	2	2	2	2	2
							N	5	5	4	5	5	5	W	2	2	2	2	2	2
							BK /T	5	5	2	2	2	2	PS-B	4	6	8	8	8	8
							L	2	2	2	2	2	2	CP	1	1	1	1	1	1
							SC (B)	8	8	6	7	7	7	TS -B	5	7	9	9	9	9
							M	1	1	1	1	1	1	TS-C	10	11	12	11	11	12
							F	3	3	3	3	3	3	A	1	1	1	1	1	1
							SC (C)	12	12	10	11	11	11							
GR	42*	43*	45*	40*	40*	40*	RLS	> 7*	> 7*	> 7*	> 7*	> 7*	> 7*	RBS	11*	12*	13*	12*	12*	13*

Low Risk-$, Medium Risk - @, High Risk - #, Very High Risk - *

BK/T-Back/Trunk, S-Shoulder, UA - Upper Arm, LA-Lower Arm, H-Hand, W-Wrist, WT-Wrist Twist, N-Neck, L- Legs, F-Force, R-Rhythm, IOE-Intensity Of Effort, SA-Self-Assessment, SC(A)- Score In Table-A, SC(B)- Score In Table-B, M-MUSCLE SCORE, ROW (C)-Score From Row In Table C, COLUMN (C)- Score From Column In Table C, PS(A)- Posture score in Table A , TS(A)- Total Score of A , PS(B)- Posture score in Table B, TS(B)-Total Score of B, TS(C)- Total score from Table C, A- Activity Score, GR-Global Risk, FS-Final Score, RBS-REBA Score, RLS-RULA Score.

Table 5: Score for all postures

ERIN							REBA							RULA						
BP	P1	P2	P3	P4			BP	P1	P2	P3	P4			BP	P1	P2	P3	P4		
				(A)	(B)	(C)					(A)	(B)	(C)					(A)	(B)	(C)
BK/T	2	2	2	2	2	2	US	1	1	1	1	1	1	N	1	1	1	1	1	1
S/UA/ LA	2	2	2	2	2	2	LA	1	1	1	1	1	1	BK/ T	1	1	1	1	1	1
H/W	2	2	2	2	2	2	W	1	1	1	1	1	1	L	1	1	1	1	1	1
N	1	1	1	1	1	1	WT	1	1	1	1	1	1	PS-A	1	1	1	1	1	1
R	3	3	3	3	3	3	SCA	1	1	1	1	1	1	F	0	1	0	0	0	0
IOE	2	2	2	2	2	2	M	1	1	1	1	1	1	TS-A	1	2	2	2	2	2
SA	1	1	1	1	1	1	F	1	1	1	1	1	1	UA	1	1	1	1	1	1
							ROW (C)	3	3	3	3	3	3	LA	1	1	1	1	1	1
							N	1	1	1	1	1	1	W	1	1	1	1	1	1
							BK/T	1	1	1	1	1	1	PS-B	1	1	1	1	1	1
							L	1	1	1	1	1	1	CP	0	0	0	0	0	0
							SC (B)	1	1	1	1	1	1	TS-B	1	1	1	1	1	1
							M	1	1	1	1	1	1	TS-C	1	1	1	1	1	1
							F	1	1	1	1	1	1	A	1	1	1	1	1	1
							COL (C)	3	3	3	3	3	3							
CR	13$	13$	13$	13$	13$	13$	FS	3@	3@	3@	3@	3@	3@	RS	2@	2@	2@	2@	2@	2@

LOW RISK-$, MEDIUM RISK - @, HIGH RISK - #, VERY HIGH RISK - *

Table 6: Biomechanical analysis score using newly proposed table for different weight

	10 KG	12 KG	15 KG	20 KG
L4/L5 moment (Nm)	-31	-37	-47	-63
L4/L5 Compression (N)	1190	1319	1513	1837
Body load compression (N)	507	526	555	604

Axial twit compression (N)	25	29	35	45
Flexion/Extension compression (N)	520	625	784	1047
L4/L5 Joint shear (N)	96(P)	107 (P)	124 (P)	152 (P)
Abdominal force (N)	0	0	0	0
Abdominal pressure (N/m2)	0	0	0	0

Table 7: Result of lift-lower analysis by CATIA

Parameters	10 KG	12 KG	15 KG	20 KG
Recommended weight limit	13.197	13.197	13.197	13.197
(RWL) (1991) Lifting Index (LI) (1991)	0.76	0.91	1.14	1.52

ERIN, RULA and REBA Score using newly proposed table

The score obtained from the ERIN, RULA and REBA methods shows that the proposed table is proficient in collecting and discharging the concrete mixture as the laborers does not need to bend forward for collecting the concrete in the iron-pan as well as lifting the iron-pan. The results of the all methods shows low to medium risk to the body parts, at the same time load on the muscles have decreases because of increase in the height of the collecting and lifting table. The postures adopted while working with new table shows that the laborers are working in the appropriate and proper postures but weight of the pan is need to be decreases to acceptable weight limit. The RULA score for 20kg in CATIA software also got the same result i.e. 4 (Medium Risk).

Biomechanical analysis score using newly proposed table for different weight

Biomechanical analysis for lifting 10kg, 12kg, 15kg and 20kg was performed in the CATIA software using this table and manikin. The study found that when laborers lifted up to 12kg weight, compression at L4/L5 was reduced to very low i.e. 1190N for 10kg and 1319N for 12 kg. However, as the weight increases these values increases i.e. for 1513N for 15kg and 1837 for 20kg. The joint shear is also observed increasing as the weight increases. The factors are also found reduced and the force and the pressure on abdomen became zero (Table 5 and 6).

Lifting score using newly proposed table for different weight as per NIOSH 1991

Table shows the NIOSH lifting analysis scores obtained from CATIA software. The analysis were performed by considering 60 second time for per lift, duration of work 8 hours, excluding break, better coupling conditions and weight lifted 10kg, 12kg, 15kg and 20kg. After analysis, the result found that the recommended weight limit (RWL) for all positions is 13.197kg. However, variable values of the lifting index (LI) obtained. For 10kg and 12kg LI obtained 0.76 and 0.91 while for 15 kg and 20 kg it is obtained more than 1 i.e. 1.14 and 1.52 respectively. Therefore, from the NIOSH lifting analysis result it is reveals that the lifting weight should not be more that 13.197 kg approximately 14kg. Lifting 14kg or less weight will bring about positive changes in the body of the labors.

DISCUSSION

The aim of this paper was to measure the effect of collecting and lifting of concrete mixtures on the body parts of the laborers. Find the effect of working in forward bent posture while collecting concrete in the iron-pan, the effect of lifting up the iron-pan from the ground and effect of lifting concrete mass having weight ranges between 18 to 21 kg on the different body parts. Also to find the most exposed body parts with remedial actions. In this study, ERIN, RULA and REBA methods and worksheets were used to find the effect of ergonomics risk. From the result of ERIN, RULA and REBA, it was found that the laborers were working in extremely vulnerable condition and their lower back, shoulders and arms/hands are highly affecting. From the different studies of postural analysis, biomechanical analysis and frequently lifting also revealed that not only heavy lifting but also low and moderate levels of loadings are also responsible for considerable injuries, morbidity and WRMSD risk.[18, 14, 19, 20, 21, 22] Moreover, more prevalence of WRMSD occurs due to repetitive activities, heavy exertion, prolong working in static and dynamics postures, high muscular activities, undue pressure on lower back, no intermittent rest, working in awkward postures, inadequate nutrition, gravity force on L4/L5 and L5/S1 of the spinal cord, wrong tools design and use, environmental effect.[23] Jones et al., 2011 also infer that peak load is also hazardous and cumulative load also have significant effect on the tissue. As per Hoozemans et al., 2008 the vertical location of the load to be lifted must be kept between 320mm to 1550mm and lifting mass should be between the 7.5kg to 15kg.

The problem with the study was also revealed that workers often had to work in a forward bending posture and lift heavy material off the ground, which eventually led to the development of work-related musculoskeletal disorders. The newly designed table is solving the problem of forward bending for collecting the concrete in the iron-pan and lifting the pan ground level. The newly designed table showed the potential to reduce the risk on lumbar and shoulder risk problems, as well as increased height of the table also reduced the risk of shoulder, arm, hands and neck injury. To find the comfortable lifting height, an experiment was also done using stands of height 500mm and 1000mm. Laborers had to bend over 90 degrees to lift the pan from the bottom, laborers had to bend 90 degree to lift from a height of 500mm but workers did not have to bend to lift from a height of 1000 mm and the iron-pan could lift easily. The proposed table was designed in CATIA software and analysis was performed on the manikin developed in the same software. ERIN, RULA and REBA analysis as well as biomechanical and lifting analysis were performed on the manikin in the CATIA software. RULA score also obtained from the CATIA and ERIN and REBA score obtained from the worksheets. RULA score obtained from the CATIA showed that when the force 20, 15 and 12 kg applied on the body, the score obtained 4 and when the force 10 kg applied on the body, the score obtained 3 which explained medium risk with further investigation. However the result obtained from the ERIN and REBA showed low risk.

The biomechanical analysis revealed that lifting weight ranged between 10-20 kg applied low compression forces and joint shear on the lumbar when working in the posture using proposed table, but it is very much low for the weight of 10 kg and 12 kg. However, the lifting and lowering analysis result showed that the recommended lifting weight should be 13.197 kg because lifting index obtained was more than one for the weight lifted more than 15 kg and less than one when lifting weight is 10 kg and 12 kg. The force and pressure on the abdomen were also obtained zero when work using proposed table. There were no twisting moment for trunk and neck. From the different result obtained from ERIN, REBA worksheet and from RULA, biomechanical and lifting/lowering analysis after proposed table and technique, it concluded that working using proposed table minimize the ergonomic risk on the body parts as well as on the vertebrae that leads to the work-related musculoskeletal disorder.

CONCLUSIONS

Laborers involved in the collection and laying of the concrete mix at construction sites are exposed to various work-related musculoskeletal risks associated with work. These WRMSD risk issues are related to lower and upper back are significant in laborers. In this study, different working poses were evaluated to find the level of exposure of the body parts to work- related musculoskeletal risk. Real time images were selected for the evaluation and ERIN, RULA and REBA methods were used for evaluation. The results of these methods show that workers face higher ergonomic risks when working in the traditional way. Workers have to work in awkward postures with frequent forward bending more that 90 degree to collect the concrete mix in an iron pan and lift it from the bottom up. This indicates a high compressive and shear load working on the spine of the laborer which requires proper contribution to reduce the risk of exposure.

Collection and discharge tables and manikin were designed in CATIA. RULA, biomechanical and lifting / lowering analyzes were performed taking into account the different loads on the manikin when working with newly designed tables. ERIN and REBA analyzes were also performed on Manikin who worked with the same. The newly designed collection and eviction table shows that using this table to lay concrete mix slab on the floor for concreting work reduces the risk associated with collecting and lifting the iron pan from the ground level and reduces the exposure of vertebral L4 / L5 and L5 / S1 while performing concrete mix laying on the floor for slab concreting work. The concrete mix can transfer using hose pipe to the bin openings to avoid manual transmission of concrete mix and also the number of eviction opening can increase as per requirement.

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