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Proposal of construction material flow index for multi-storey residential buildings.

Propuesta de índice de flujo de materiales de construcción para edificios residenciales de varios pisos.

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ABSTRACT

Besides water, construction materials are indeed the major flows that enter the sites. Administration and movement of these supplies are the challenges experienced on sites nowadays due to the scarcity of materials, delays in terms of availability, inefficient transport facilities, damage and waste and limited space for storage. Effective flow of material is very critical for maintaining a productive and cost efficient location. Poor disposal and haulage during site operations is an important issue that jeopards the efficiency of construction projects. Unsatisfactory handling, storage and management of materials on work sites will seriously hinder the performance of the project. In construction site, a new approach is therefore required to analyze the flow of materials. The project deals with the identification of optimum material flow factors identified from literature review and analysed for index generation by developing formula for index. This includes measures of material movement, its consumption and excess disposal of waste. The proposed construction flow index (CFI) is a composite indicator that illustrates the repetitive construction project efficiency of the output flow. The CFI is a powerful instrument for assessing the efficiency and effectiveness of construction projects and monitoring the movement of supplies. An index is generated for the quantitative analysis of the material flow at work sites in this project.

Keywords— material flow, CFI, construction projects, material management.

RESUMEN

Además del agua, los materiales de construcción son de hecho los principales flujos que ingresan a los sitios. La administración y movimiento de estos insumos son los desafíos que se experimentan en los sitios hoy en día debido a la escasez de materiales, retrasos en la disponibilidad, instalaciones de transporte ineficientes, daños y desperdicios y espacio limitado para almacenamiento. El flujo efectivo de material es fundamental para mantener

una ubicación productiva y rentable. La eliminación y el transporte deficientes durante las operaciones del sitio es un problema importante que pone en peligro la eficiencia de los proyectos de construcción. El manejo, almacenamiento y manejo insatisfactorios de materiales en los sitios de trabajo obstaculizarán seriamente el desempeño del proyecto. En el sitio de construcción, por lo tanto, se requiere un nuevo enfoque para analizar el flujo de materiales. El proyecto se ocupa de la identificación de factores de flujo de material óptimos identificados a partir de la revisión de la literatura y analizados para la generación de índices mediante el desarrollo de fórmulas para índices. Esto incluye medidas de movimiento de material, su consumo y el exceso de eliminación de residuos. El índice de flujo de construcción propuesto (CFI) es un indicador compuesto que ilustra la eficiencia del flujo de salida del proyecto de construcción repetitiva. El CFI es un poderoso instrumento para evaluar la eficiencia y efectividad de los proyectos de construcción y monitorear el movimiento de suministros. Se genera un índice para el análisis cuantitativo del flujo de materiales en los sitios de trabajo de este proyecto.
Palabras clave: flujo de materiales, CFI, proyectos de construcción, gestión de materiales.

INTRODUCTION

Construction industry is essential as it changes the face and function of towns and cities and plays a vital role in the socio-economic growth of a country. To promote the circular economy and resource efficiency in the construction industry, information on Material Flow Analysis (MFA)and stocks is a necessary content. Material Flow Analysis (MFA) quantifies material flows and stocks in sites which is used to analyze specific material's consumption, wastage etc. Flow of material in sites are considered vital to achieve better productivity, profit and also at the same time to reduce wastage. Therefore proper management of this single largest component can improve the productivity and cost efficiency of a project and help ensure its timely completion. One of the major problems in delaying construction projects is poor materials and equipment management. Effective management of materials flow represents a great potential for improving productivity of work and also controlling cost uptoa certain extent. In this paper an index is generated to quantify the material flow in construction sites. The proposed construction material flow index (CMFI) is a valuable tool to evaluate the quality and performance of construction activities and to measure the flow. It is a composite measure that reflects the quality of production flow in repetitive construction projects. It gives an accurate measurement of the stocks, disposal of the surplus and their flows in general.

LITERATURE REVIEW

Firstly the optimum material flow factors affecting multi-storey residential buildings are identified. A questionnaire survey was conducted to get accurate responses. It was distributed to construction professionals including supervisors, site engineers, project engineer and structural engineers. Eleven factors were identified for the study and were ranked by Relative Importance Index (RII) method. Factors having an RII value of 0.9 and above were used for the study. The quantities of steel and concrete supplied and consumed were calculated from different sites for piling, column and beam works. Calculation of construction wastes were estimated for various works such as piling, casting of beam and column. An index is generated for calculating the flow of materials for various sites for works such as piling, beam and column.

IDENTIFICATION AND RANKING OF FACTORS: The optimum factors that affect the material flow in construction sites are identified through literature review and questionnaire survey. Relative Importance Index method (RII) was used for ranking the factors. Out of the eleven factors identified, only four main factors were considered for the study having an RII value of 0.9. The questionnaire was checked for reliability and was found that the measuring criteria Cronboach's Alpha was 0.805, which was found to be better. RII method is done to measure the consistency of the questionnaire.

Table 1:Ranking for factors influencing optimum flow of materials on site

S.NO	DATA	RII	RANK
1	Defining accurate material requirements	0.985	1
2	Check whether design changes made or not, if any	0.966	2
3	Preparing for material schedule	0.935	3
4	Rework or Re entrant flow	0.904	4
5	Using safe storage facilities	0.823	5
6	Planning and monitoring of construction activities	0.804	6
7	Daily recording of using materials on site	0.721	7
8	Considering required communication methods for material management	0.624	8
9	Reporting the situation of materials in the store	0.620	9
10	Performing recycle and reuse methods for surplus and waste materials	0.535	10
11	Controlling over-ordering and purchasing	0.510	11

CALCULATION OF CONSTRUCTION WASTES: Quantity take offs are important for understanding the material needs of a project. Drawings, blueprints, or models are essential criteria for estimating the accuracy of flow of materials. It plays a major role in the final detailed estimate of a project with labour costs, equipment costs etc. It is possible to estimate the percentage of materials being used and wasted by this method. Material flow factors help in measuring the accurate flow of materials in a timely manner assuring minimum wastage.

Table 2:Calculation of quantity for piling work

PILING						
SITES	STEEL			CONCRETE		
	Qty supplied (kg)	Qty consumed (kg)	Wastage (%)	Qty supplied (m^3)	Qty consumed (m^3)	Wastage (%)
Site 1	47223	46434.310	1.67	920.602	839.405	8.82
Site 2	900711.800	885663.190	1.95	19621.620	18600	5.26
Site 3	704088.270	689888.021	2.37	13794.945	13098.301	5.05
Site 4	724849.101	712744.122	1.05	16244.217	15099	7.05
Site 5	52090.695	51002	2.09	1034.991	982	5.12
Site 6	41821	40759	2.54	960.481	802.092	9.64
Site 7	86300.210	85299	1.16	11104.328	9780.147	9.21
Site 8	35308.921	34602.743	2.00	803.538	753.960	6.17
Site 9	7556.140	7438.998	1.55	466	429	8.00
Site 10	38107.977	36968.549	2.99	851.786	785.092	7.83

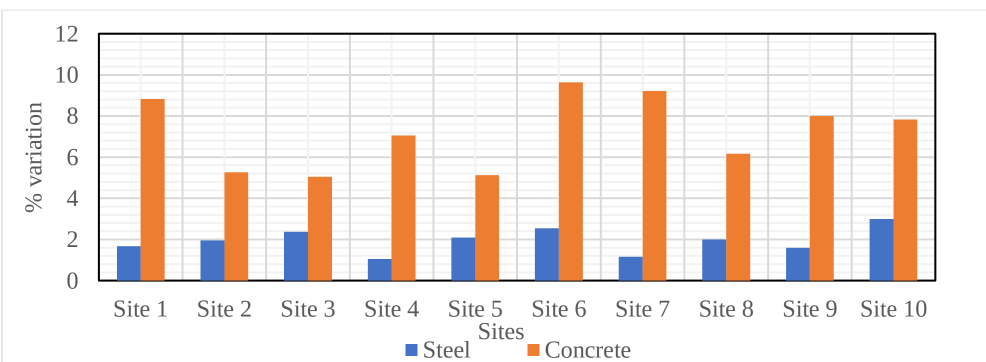

Fig 1:% of wastage of steel and concrete of different sites

As shown in fig 1, wastage of concrete is more in all sites when compared to steel wastage. Usually incase of piling due to improper material schedule and unskilled labour results in a much higher wastage in concrete. Also in table 2, it is clear that site 2 consumes a major quantity of both steel and concrete when compared to other sites. The wastage of steel is higher in site 10, lower in site 4 and that of concrete higher in site 6, lower in site 3.

Table 3: Calculation of quantity for casting of beam

BEAM						
	Steel			Concrete		
Sites	Qty supplied (kg)	Qty consumed (kg)	Wastage (%)	Qty supplied (m^3)	Qty consumed (m^3)	Wastage (%)
Site 1	11952.313	11802.910	1.25	54.008	53.290	1.33
Site 2	26896.425	26205.187	2.47	124.342	121.035	2.66
Site 3	23182.397	22804.524	1.63	109.770	107.410	2.15
Site 4	21098.087	20520	1.74	90.928	90.010	1.01
Site 5	12938	12695.300	1.88	58	56.260	1.79
Site 6	10326.551	10201.600	1.21	48.422	47.226	2.47
Site 7	13115.459	12802	2.39	64.790	64	1.22
Site 8	7506.347	7320.190	2.48	38.205	37.690	1.35
Site 9	2643.336	2616.110	1.03	11.185	11.040	1.30
Site 10	9193.461	9009.592	2.00	42.261	41.750	1.71

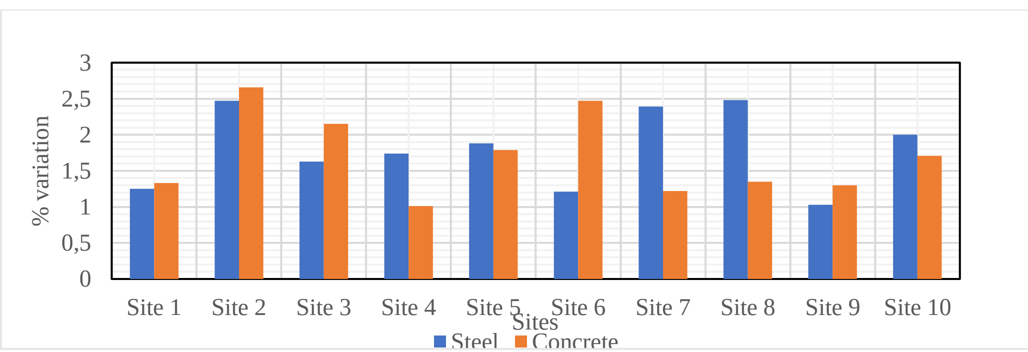

Fig 2:% of wastage of steel and concrete of different sites

As shown in fig 2, both steel and concrete are equally responsible for contributing towards wastage in all sites. Incase of beam, due to improper material schedule, rework, design changes etc results in a much higher wastage of both steel and concrete. Also in table 3, it is clear that site 2 (131 beams) consumes a major quantity of both steel and concrete when compared to other sites. The wastage of steel is higher in site 8 (42 beams), lower in site 9(29 beams) and that of concrete higher in site 2 (131 beams), lower in site 4 (109 beams).

Table 4: Calculation of quantity for casting of column

COLUMN						
	Steel			Concrete		
Sites	Qty supplied (kg)	Qty consumed (kg)	Wastage (%)	Qty supplied (m^3)	Qty consumed (m^3)	Wastage (%)
Site 1	19375.446	18986	2.01	47.948	47.100	1.77
Site 2	41326.553	39499.920	4.42	106.979	103.824	2.95
Site 3	34042.876	32378.180	4.89	87.310	86.210	1.26
Site 4	38924.421	37854	2.75	102.536	99.490	3.00
Site 5	22187.368	21078	5.00	54	53	1.85
Site 6	13982	13500	3.45	33.879	33.110	2.27
Site 7	25245.846	24041.620	2.05	58.787	58.170	2.98
Site 8	7779.446	7615.300	2.11	21.607	21.080	2.44
Site 9	5066.006	4912	3.04	12.310	12.120	1.55
Site 10	11962	11507.050	3.80	30.844	30.212	2.05

From table 4, it is clear that site 2 (72 columns) consumes a major quantity of both steel and concrete when compared to other sites. The wastage of steel is higher in site 5 (37 columns), lower in site 1 (34 columns) and that of concrete higher in site 4 (69 columns), lower in site 3 (64 columns).

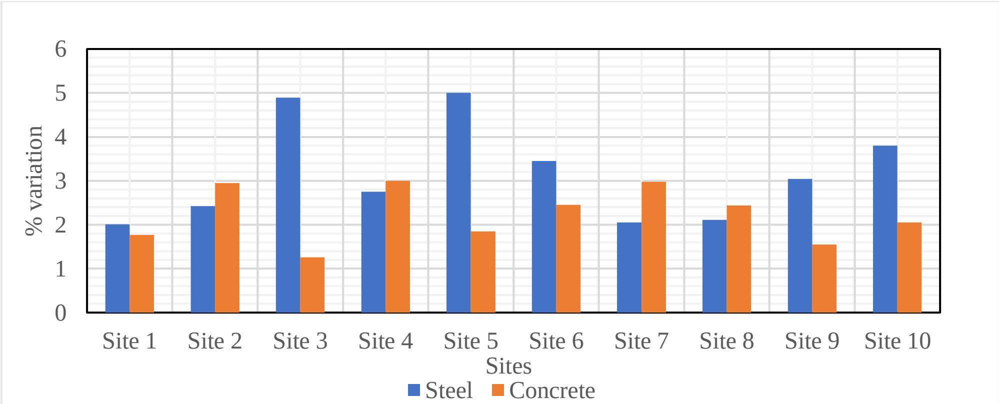

Fig 3:% of wastage of steel and concrete of different sites

As shown in fig3, comparatively steel is responsible for contributing towards wastage in all sites. In case of column, due to improper material schedule, rework, design changes etc results in a much higher wastage of both steel and concrete. Steel wastage is due to extra rings made, improper cutting etc.

CONSTRUCTION MATERIAL FLOW INDEX (CMFI)

CMFI is a composite measure to quantify the flow of materials by reflecting the quality of material flow in repetitive construction projects and thereby measuring the wastage occurring in sites. Eleven variables are identified using RII analysis and computed weights for each normalized variable, adding the components to provide the scaled index. The CMFI was developed through a series of steps. Define a set of optimum material flow conditions, estimate the quantity of material for each work, establish the weights for each parameter and develop CMFI formula by using STAN software. STAN software was used for analysing the material flow in sites with the help of quantities being consumed, supplied and wasted. It also helps in developing a flow network for piling, beam and column works. An Equation for CMFI is given below.

$$\mathrm{CMFI} = \sum \mathrm{WiPi} \pm 10\%$$

where Wi – Weight of each parameter (taken from RII value)

Pi – Parameters P1 to P4

i – 1 to n, where n = 4

P1 - Material requirement
P2 – Design changes
P3 – Material schedule
P4 - Rework or Re enterant flow
y – Wastage of material in the site

$$\mathrm{Pi} = 0.985\mathrm{P1} + 0.966\mathrm{P2} + 0.935\mathrm{P3} + 0.904\mathrm{P4}$$

Table 5: CMFI values for steel and concrete

Sites	Piling		Beam		Column	
	Steel cmfi	Concrete cmfi	Steel cmfi	Concrete cmfi	Steel cmfi	Concrete cmfi
Site 1	7.25	6.70	2.14	1.18	4.62	5.21
Site 2	7.80	3.84	1.26	3.21	5.01	2.98
Site 3	4.21	1.08	2.39	1.77	3.08	1.98
Site 4	2.03	8.08	3.87	2.52	4.53	4.37
Site 5	2.75	5.67	2.18	1.76	6.81	8.18
Site 6	3.20	9.61	3.21	3.21	3.24	3.79
Site 7	1.89	8.27	5.59	4.06	7.84	6.96
Site 8	6.77	4.95	3.57	2.47	5.14	4.14
Site 9	8.02	6.15	2.02	4.60	2.14	9.72
Site 10	5.14	5.05	4.20	6.88	3.27	8.14

From table 5, it is clear that CMFI value for steel is higher in site 9, lower in site 7 and CMFI value for concrete is higher in site 6, lower in site 3 for piling. Incase of beam, the CMFI value for steel is higher in site 7, lower in site 2 and CMFI value for concrete is higher in site10, lower in site 1. Incase of column, the CMFI value of steel is higher in site 7, lower in site9 and CMFI value of concrete is higher in site 9, lower in site 3. Lower CMFI values indicate that the flow of material is stable with minimum wastage, lower design changes, rework and accurate material requirements and schedule as per plan.

As conclusions, the study focuses on MFA in construction sites during the construction period of a multi-storey residential building. The result has highlighted the fact that index generation for multi-storey residential building construction was determined by evaluating material consumption, supply of quantity of material, design changes, rework or re-entrant flow, material schedule, wastage due to improper transportation equipments and machineries, storage facilities etc generated by a linear equation using STAN. Eleven factors analysed through the questionnaire survey were found to be reliable as the Cronboach's Alpha is 0.805. The analysis shows that, the most significant contributor towards the material flow analysis is material requirement with 0.985 RII value, design changes with 0.966 RII value, material schedule with 0.935 RII value, rework or re-entrant flow with 0.904 RII value. Construction material flow index for each work such as piling, beam, column using steel and concrete in multi-storey residential building have been developed using STAN software. The results indicate that both steel and concrete are equally responsible for contributing towards wastage of materials in various sites. The wastage of steel is between 1 - 3% and concrete between 5 – 10% for piling. For casting of beam, the wastage of steel is between 1 – 3% and concrete between 1 – 2%. For casting of column, the wastage of steel is between 2 - 5% and concrete between 1 - 3%.It helped to predict the effective material flow for each work in sites. In other words, the CMFI predicts an accurate material flow, and also the impacts of their efforts to control it, visible and tangible.

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