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Rebar wastage in building construction projects of Hawassa, Ethiopia

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Abstract— Improper way of using steel reinforcement in concrete incurs undue wastage of money in the construction projects. Wastage of rebar can be realized even at the design stage and can propagate through every stage of construction process. Brief objective of the present study was to analyze the factors influencing wastage of steel in building constructions of Hawassa town and to recommend the best practices to reduce rebar wastage. The study was conducted on 17 buildings sites and their respective offices, based on data collection and analysis by questionnaires, content analysis method and participatory observations. The study respondents were contractor's and consultant's managers, designers, bar benders, supervisors and quantity surveyors. Central value analysis, correlation and regression analysis were conducted on the data collected, using SPSS software to confirm the factors influencing the wastage of steel. The cost estimated in bill of quantity and the final cost after the provision of the steel with any alterations were compared and the reasons for cost overrun were analyzed. The influencing factors for wastage of steel were more concentrated in the part of design and detailing. By the results of analyses, best practices such as design and decision changes shall not happen while construction is going on, design and detailing provisions based on codes shall be followed correctly, bar benders shall be educated to work as per detailing given by designer and supervision by engineers shall be extended during bar bending job were suggested to minimize cost overrun due to rebars wastage.

Index Terms— bending gain, cost overrun, detailing, rebar, steel, wastage

1 Introduction

As building construction project is a business involving many materials in huge quantities, labor and qualified engineers, possibility of material wastage and its subsequent influence in total cost of building is quite common. Mediations and compromises between the client, consultant and contractors with respect to quality and cost cannot be avoided but it is better if it approaches to have appreciable quality with lesser cost. One of the major factors contributing the cost minimization is to reduce wastages. If it is aimed to reduce wastages, naturally it could result in better quality and productivity, as concentration is paid in how to use the material effectively [1].

Even though building construction is a business for the client who pours money into it, it is experience, challenge and adventure, on every day, for consultants, architects and engineers apart from the earnings that any participant gets. Building construction is a long journey, from the inception to the time of completion, with many participants, materials, technologies, machineries, schedules, energies and last but not the least, uncertainties. The construction activity contributes to life of many workers and engineers, improves the status of the users and ultimately adds its share to up-build the GDP of the country. If such are the benefits of the construction, the participants are expected to follow the scientific way of avoiding any loss in any form. But in the real field of construction, there are more uncertainties which cause losses and which override the best practices that safeguard the dignity to be in this field of profession. One among the uncertainties is the improper ways of working with reinforcements that influence cost overrun in the construction projects.

Many researches have addressed about the construction material wastage in general, its causes, remedies, its effect on environment, cost of projects and related issues. Out of the literatures referred, very few researches were involving steel. According to the findings of Baytan [2], the average percentage of wastage of steel by comparing quantity used and quantity delivered to site was 7.5% which can be considered as very meager percentage in total cost of building. Based on the experiences of practicing engineers steel's wastage in building construction is around 5% [3]. But many researchers found that the quantity exceeds this acceptable value.

The present attempt is aimed to analyze the causes, remedies and extent of wastages of steel, in the construction sites of Hawassa town, either directly or indirectly in the form of misuse, and its effect on the cost of building. Misusing steel or causing wastage of steel in building construction were understood to happen at the procurement stage, material handling stage and at the design stage [4]. The use of grades of steel other than that used in the design and design alterations may become common due to the market availability or non-availability of certain grades, which in turn can influence reworking and the unsafe use of the material [5]. Though safety factors are being in use in the design philosophy, additional safety measures could be employed by the designers by increasing meaninglessly some quantity or length of reinforcement. Thus at the design stage there are possibilities to use excess quantity of steel than that is required. Good practice of producing and using bar bending schedule (BBS) can minimize the wastage of steel [6], [7]. But in many sites BBS are not being supplied. Skilled bar benders, dedicated to work perfectly can, really, optimize the use of steel by avoiding more numbers of cut bits, excess lengths left without cutting

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1.1 Problem statement

Steel is one of the costliest materials being used in building construction. In general, in the building construction activities, there is less attention paid in using steel right from the estimating stage to the placement of reinforcement for concreting and also during concreting to compact well. At the time of estimating, guessing about the quantity of steel required without doing meticulous calculations can also lead to the use of greater quantity of steel than required. Optimum use of steel could be properly assessed and wastages may be minimized. The grades of steel are not standardized at the country level and different makes are available in the market, which can influence the safe use of the material and also cause design alterations. In Ethiopia, most of the regions are highly earthquake prone, hence detailing and scheduling of reinforcements should be made with respect to the coded information. While in the field of practice, for low rise buildings of around 10 stories and less (more found in Hawassa), the rebar detailing is not found to be on par with the coded detailing procedures. The bar scheduling can show its effect over economy as it concerns with measurements. Uncertainties are also possible to observe in the way of cutting, bending and positioning the reinforcements. Ignoring bending gains, not following the bar bending schedule for the easiness to exercise while bar bending could result in over use of steel. Hence, in this research, the authors decided to address the issues of the effect of reinforcements' misuse in cost of the construction project. There are some other aspects of hazardous situations for the misuse of reinforcements like improper storage due to which corrosion propagates in concrete, cost fluctuations in the market, etc., which are not taken into account in this research.

2 Methodology

The study was conducted in the building construction projects of Hawassa town. Descriptive/diagnostic type of research was preferred to undertake. As the participants had the similar features, random sampling technique was adopted for the selection of sites as a sample unit. Stratified sampling method was used to collect data from questionnaire survey to adjudge the effect of grade and make, as the respondents were of different working groups like bar benders, supervisors, designers etc. For adjudging the effect of detailing, scheduling, bar bending and cutting, systematic sampling method was used as the samples could be spread more evenly over the entire population and as there are no expectations of hidden periodicity in the population.

Seventeen building construction sites with total floor area of the building between 500 m^2 and 1500 m^2 and with at least 3 storeys were selected within Hawassa town. Out of seventeen buildings considered for survey, 14 buildings were finally used for analysis of results as some uncertainty prevailed had influenced the consistency of the results. The construction activities in the sites so selected were at different stages like at the first storey level or and higher storey levels, in parallel working with finishing jobs.

The study respondents were contractor's and consultant's managers, designers, bar benders, supervisors and quantity surveyors. Totally 5 respondents in every site were selected while 4 responses were considered for analysis as drop-outs in some of the sites were common.

The research design constitutes sampling design, observational design and also operational design. Data were collected by questionnaires, participative observations at sites and content analysis by checking the documents related to quantity surveying, detailing and rebar scheduling. Questionnaire surveys helped to assess about the influence of different factors on wastage/misuse of steel. In this survey, to know about design alterations due to market unavailability of certain diameter of bars, frequency of design alterations and effects on total cost, reasons for design alterations, effect of easiness to work with certain makes and its influence in total cost due to the bar benders delays etc. well-structured questions of open and closed ended type were framed. Site observations were conducted with participation of site members/engineers, to assess about the effects of detailing, scheduling, cutting and bending of bars apart from questionnaire. Sufficient information was collected through the already prepared documents available in the site and consultants office related to the quantity surveying. Checking of values, correctness of design, appropriate use of coded information for designs and quantity calculations were done as part of content analysis method.

After editing, coding and classifying the data collected, central value analysis, correlation and regression analysis was performed using SPSS software and Excel sheets.

3 Results and discussion

Based on the questionnaire survey and interviews with the participants of the constructions, firstly, the factors responsible for the rebar misuse/wastage were assessed. The major factors observed were, grade, make, purchase procedures, cutting, bending, structural design and detailing.

3.1 Influence of grade, make and purchase procedures in rebar wastage

From the analysis of questionnaire survey and interviews, it was found that the bar benders prefer to use lower grade of steel which could be easily bent. Figures 3.1 and 3.2 shows the bar benders' grade preference and respondents' perspective over market availability of different grades of steel respectively. About 67% of respondents have committed that working with S300 is easier while 13% have felt to work with the design specification which is mentioned as neutral. 73% of respondents, have answered that S300 is quite commonly available to purchase whereas the remaining percentage of respondents have committed that even S420 is also available to easily purchase and use. As rare cases, while higher grade steel has to be used as per the design, design alterations have come into play to fulfill the easiness of the bar benders to use lower grade of steel. Moreover, in the market commonly available grade is S300. The strength values of rebars are not known to the dealers who sell due to the certificates of quality assurance not being supplied to the dealers. But these reasons have shown insignificant impact over cost increase of the steel.

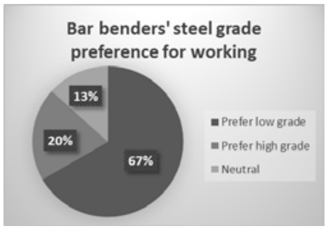

Figure 3.1 Bar benders' grade preference

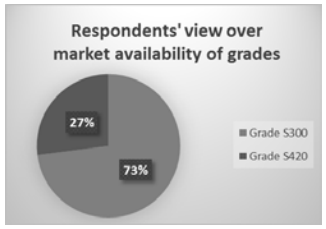

Figure 3.2 Market availability of grades

Table 3.1 shows the opinion of the respondents with respect to the procurement of steel. Likert scale was used to check the influences of particulars as given in the Table 3.1. 73% of the respondents reported that the purchase had been done other than that is used in the design. Also over ordering had also happened due to mistakes in quantity surveying and due to lack of coordination between the construction crews. But fortunately, purchasing a higher grade of steel than that is used in the design was committed to be of low percentages. Hence the analysis shows that money loss is found to happen due to quantifying and due to lack of co-ordination.

Table: 3.1 Influence of procurement of materials

No.	Particulars	5	4	3	2	1
		%	%	%	%	%
1	Procuring of materials irrelevant to project requirements defined on design documents	16.67	73.33	6.67	3.33	0
2	Excess purchase due to errors in quantity calculations	20	70	3.33	6.67	0
3	Excess purchase due to deficiency of coordination between purchase and construction crews	16.67	76.66	0	6.67	0
4	Purchasing lesser quantities than required	0	0	13.33	10	76.67
5	Purchase of expensive material with high performance	0	3.33	3.33	26.67	66.67
	5=Very high 4= High 3 = Moderate 2 = Low 1 = very Low					

Apart from the analysis by questionnaire and interviews as given above, the strengths steel from different manufactures were checked by conducting tension test on specimens and the results are summarized in Table 3.2. The results show that the strength of the samples from all the manufacturers were adequate and satisfactory.

Table 3.2 Strength of different steel grade and make available in market

Grade	Make	Diameter mm	Weight Kg/m	Yield strength N/mm²	Ultimate strength N/mm²
S300	Turk	12mm	0.888	319	463
S420	Turk	12mm	0.889	432	549
Grade40	Akaki	14mm	1.210	325	467
Grade60	Akaki	16mm	1.577	436	547
S300	Zuquala	12mm	0.889	315	459
S300	Apollo	10mm	0.616	322	463
S300	Abissynia	12mm	0.886	318	456

3.2 Influence of cutting, bending, detailing and scheduling in wastage of steel

After the detailed investigation through questionnaire and interviews, the factors that were prominently being spoken as influencing the wastage/misuse of steel and thereby the cost, were sorted out to be of 10 in numbers as listed below. Analysis of results under this head was performed using 10-point scale. The factors are,

1. Extending bars more than the required length/not following exactly BBS (Extending bars)

Either in the BBS or in structural design drawing, length of bars to be cut is specified. But the bar benders most often do not take care to optimize the use of 12m long bars, as supplied from manufacturers, to cut for the definite requirement, without leaving short unusable pieces. Instead, there were extended bars more than the given length found in the sites.

2. Short unusable pieces produced after cutting & left uncared (Short cut pieces)

This could be another factor related to the first one, i.e. to leave some unusable short pieces after cutting the bars to the exact requirement as per the BBS or structural design drawing.

3. Non-optimized cutting of bars (Non-optimized cutting)

This refers to the non-optimized cutting of 12m long bars as supplied. This also can lead to unusable pieces and/or over sized pieces which can be used, but not economical.

4. Mistake in cutting/ Use of incorrect dia of bars, thus reworking (Mistake and Rework)
5. Poor supervision by qualified engineer during cutting and bending (Poor Supervision)
6. Structural design and detailing not to standard (Des, detail not to std)

This factor may influence the misuse of steel if the design parameters such as loading, load combinations, envelope effect are considered improperly and if the detailing provisions are not followed based on coded standard.

7. Bar bending schedule not properly supplied from design office. (BBS not supplied)

If the BBS is not supplied from the design office, the bar benders use their own way of bending having some little guidance from the structural drawings. This can lead to erroneous length calculations that could be committed by the bar bender and in fabrication delay and sometimes unevenness in similar sort of fabrication requirements.

8. Bending gain not considered while detailing (Bend gain not used)

When the bar is bent, there is an elongation of bar length. This elongation of length is called bending gain. While detailing, the designer's crew should consider this length as excess and the length of the bar to be bent can be cut to a lesser length than the required length, considering bend gain. If it is not considered, there is an excess quantity of steel that is used in the design.

9. Design alterations were more (More design altr)

If there are design alterations, there are possibilities of mismatch between the quantity calculated for BOQ and the quantity used at the end.

10. Poor software usage for bar bending schedule preparation (Poor software Usage)

If softwares are used for BBS, manual errors and there by some wastages of quantities can be avoided.

3.2.1 Analysis based on Mean and Standard Deviation

The points given by the respondents for different factors as shown in Table 3.3 are based on both questionnaire and interview. Based on mean values of responses from all the fourteen sites, if the factors are ranked, ignorance of bending gain while detailing ranks first, BBS not been supplied ranks second, noncompliance of design and detailing to some better standard stands third and extending bars beyond which it is not required stands fourth. Even though the sites are different the work culture was almost similar and the nature of responses were also close to each other. Hence ranking by mean was also considered as one of the results. Moreover, for the above said top ranking factors the standard deviation values were found to be very low such as 0.82, 1.29, 0.8 and 1.44 while the means were as high as 8.54, 7.7, 7.18 and 5.75. This inferred that the normal distribution was fairly closer and thus the responses were reliable.

Table 3.3 Influence of cutting, bending, detailing and scheduling in wastage of steel (Responses out of 10 points)

Factors → / Buildings ↓	Extening bars	Short cut pieces	Non-optimized cutting	Mistakes and Rework	Poor Supervision	Des, detail not to std	BBS not supplied	Bend gain not used	More Design altr	Poor software usage
B1	9	7	7	5	3	9	9.5	9.75	7.75	5.75
B2	6	2.5	2	2.5	2.75	8	8.5	8.75	1.75	2.75
B3	4.75	2	1.5	1.5	2	7	6.75	8.5	1.75	2.5
B4	5	2	2.75	2.5	2.75	7.25	8.25	9.25	5.25	4
B5	5.5	2	2	2.75	2	6.75	7.25	9	1.75	2.5
B6	6	2.25	1.5	2.75	2	7	7.25	8.5	1.5	3.25
B7	8	5	3.75	4.25	3.25	8.25	9	9	4	4
B8	7.5	5	4	4	2.25	7	8.75	8.75	3.25	3
B9	5	2	2	1.75	1.75	6.75	6.75	8	1.75	2.5
B10	4.75	1.75	2	2.25	2.25	7	8.25	8.75	5	2.75
B11	5	2	1.5	1.75	1.75	6.5	7.75	8	3.75	2.25
B12	3.25	1.75	1.5	1.25	1.75	5.5	4	6.25	1.75	2
B13	5.25	3	2.75	2.25	2.75	7.25	8	9.25	2.25	2.5
B14	5.5	2.25	2.25	2	2.25	7.25	7.75	7.75	1.5	2.25
Mean	5.75	2.89	2.61	2.61	2.32	7.18	7.70	8.54	3.07	3.00
Std Dev.	1.44	1.54	1.44	1.06	0.48	0.80	1.29	0.82	1.81	0.96

3.2.2 Content Analysis

By the content analysis of documents collected from the various sites, the quantity of steel calculated in BOQ and the total quantity of steel used at the end of the projects were compared as shown in Table 3.4. and cost overrun in steel usage was calculated. For fourteen sites, the quantity of steel used up to the end of the projects exceeded the quantity of steel calculated in BOQ. For three of the sites, the quantity used were less than the quantity estimated in BOQ. Hence to have the homogeneity and to consider the majority of uniqueness, only fourteen sites, which experienced cost overrun in steel usage were considered for analysis. Unexpectedly, in one of the sites, the cost overrun was estimated to be as high as 8.81. Hence that site was selected to undergo case study.

Table 3.4 Steel quantity estimated, used and cost overrun

Building	Floor area m^2	No. of Storeys	Total floor area m^2	On BOQ		Actual Expenditure		% Cost Overrun
				Qty of steel kg	Cost of steel Birr	Qty of steel kg	Cost of steel Birr	
B1	270	5	1620	49239.06	3693345.17	53575.34	4018602.78	8.81
B2	463	4	2315	59768.37	4286897.14	62045.16	4450200.31	3.81
B3	250	4	1000	44963.73	2674000.65	45653.09	2714997.01	1.53
B4	335	4	1675	50218.23	3786525.34	52460.78	3955616.77	4.47
B5	360	5	2160	55404.51	3961440.78	56945.82	4071644.95	2.78
B6	437	4	2185	56236.63	3906270.48	57577.35	3999398.66	2.38
B7	283	4	1132	34355.03	2311948.36	36731.33	2471863.31	6.92
B8	320	3	960	30426.26	2067840.21	32010.50	2175508.89	5.21
B9	419	5	2514	62717.80	4829394.56	63934.57	4923088.25	1.94
B10	346	4	1384	35032.71	2470088.83	36288.33	2558620.18	3.58
B11	384	5	1920	52253.82	3876160.62	53880.81	3996849.87	3.11
B12	445	6	2670	64714.74	4943130.76	65486.96	5002115.54	1.19
B13	298	4	1490	36358.31	2656670.45	37430.90	2735043.68	2.95
B14	378	5	1890	52748.58	3853030.99	53750.36	3926206.22	1.90

3.2.3 Correlation between individual causing factors and cost overrun

Having the percentage cost overrun as shown in Table 3.4 and the response points of different factors influencing the wastage of steel as shown in Table 3.3, correlation analyses were performed to compare the effect of individual factors on cost overrun.

Table 3.5 shows the correlation of cost overrun percentage with one of the factors, extending bars. Similarly, correlations of cost overrun percentage with other influencing factors were also performed and the coefficient of correlation, 'r' values are shown in Table 3.6.

The correlation coefficient 'r' values were found to be very close to 0.9 (Table 3.6) for most of the factors that explains positive correlation between cost overrun occurred and the factors identified as responsible for such cost overrun. For few of the factors such as poor supervision, BBS not been supplied, bend gain not used, design alterations and design and detailing not to standard code reference the correlation coefficient is between 0.6 to 0.9 which could be considered medium positive correlation. Hence for the samples and responses to be wholesome the result of correlation was found to be satisfactory. And thus, the ranking factors based on arithmetic mean, can be considered as the major influencing factors for the cost overrun.

Table 3.5 Correlation between cost overrun percentage and the causing factor, extending bars

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Bldngs	X	Y	XY	X^2	Y^2
B1	8.81	9	79.26	77.56	81
B2	3.81	6	22.86	14.51	36
B3	1.53	4.75	7.28	2.35	22.56
B4	4.47	5	22.33	19.94	25
B5	2.78	5.5	15.3	7.74	30.25
B6	2.38	6	14.3	5.68	36
B7	6.92	8	55.34	47.84	64
B8	5.21	7.5	39.05	27.11	56.25
B9	1.94	5	9.7	3.76	25
B10	3.58	4.75	17.02	12.85	22.56
B11	3.11	5	15.57	9.69	25
B12	1.19	3.25	3.88	1.42	10.56
B13	2.95	5.25	15.49	8.7	27.56
B14	1.9	5.5	10.45	3.61	30.25
Σ	50.58	80.5	327.82	242.77	492

X=% cost overrun

Y=Points obtained in 10 point scale for the considered factor, Extending bars more than the required length/not following BBS

No of samples 'n' = 14

Correlation Coefficient 'r' = 0.88

Table 3.6 Co-efficient of correlation 'r' values for different factors influencing cost overrun.

Factors	Extending bars	Short cut pieces	Non-optimized cutting	Mistake & Rework	Poor Supervision	Des, detail not to std	BBS not supplied	Bend gain not used	Design alterations	Poor software usage
'r'	0.88	0.89	0.90	0.93	0.78	0.81	0.78	0.68	0.82	0.89

3.2.4 Regression between individual causing factors and cost overrun

Regression analysis was conducted between the dependent variable, the cost overrun and the independent variables, the factors responsible for cost overrun. The estimated value of cost overrun (X^) was found to be very close to the actual values of cost overrun (X). Thereby the analysis expressed that the factors have close relation as causes for the cost overrun. As an example, the Table 3.7 shows the regression analysis between cost overrun percentage and the causing factor, extending bars wherein X^ values were found to be close to corresponding X values. The standard error and significance were observed as shown in Table 3.8. The standard error in the regression line plot for the different causing factors were between 0.77 and 1.53 which are very low and acceptable values when compared to the mean value. Significance values for all the factors were too less like 0.00…, which shows that the regression line can be linear without 0-degree inclination. Figure 3.3 shows the regression line drawn for one of the causing factor, extending bars. This proves that the significance and X^ values can be reliable values. Thus the relation between the dependent and independent variables is considered to be strong.

Table 3.7 Regression between cost overrun percentage and the causing factor, extending bars

X^	X	Y	XY	X^2	Y^2	$(X-X^\wedge)^2$
7.74	8.81	9	79.26	77.56	81	1.14
3.93	3.81	6	22.86	14.51	36	0.01
2.34	1.53	4.75	7.28	2.35	22.56	0.66
2.66	4.47	5	22.33	19.94	25	3.25
3.3	2.78	5.5	15.3	7.74	30.25	0.26
3.93	2.38	6	14.3	5.68	36	2.39
6.47	6.92	8	55.34	47.84	64	0.2
5.83	5.21	7.5	39.05	27.11	56.25	0.39
2.66	1.94	5	9.7	3.76	25	0.52
2.34	3.58	4.75	17.02	12.85	22.56	1.54
2.66	3.11	5	15.57	9.69	25	0.2
0.44	1.19	3.25	3.88	1.42	10.56	0.57
2.98	2.95	5.25	15.49	8.7	27.56	0
3.3	1.9	5.5	10.45	3.61	30.25	1.95
Σ	50.58	80.5	327.82	242.77	492	13.1
MEAN	3.61	5.75				

n= 14
r= 0.88
A= 60
B= 29.13
C= 36.96
b= 1.27
a= -3.68
Std Error= 0.97

X=% cost overrun

Y=Points obtained in 10 point scale for the considered factor, Extending bars more than the required length/not following BBS

Table 3.8 Standard error and significance of different causing factors by regression

Factors	Extending bars	Short cut pieces	Non-optimized cutting	Mistake & Rework	Poor Supervision	Des, detail not to std	BBS not supplied	Bend gain not used	Design altrations	Poor software usage
Std. Error	0.97	0.93	0.89	0.77	1.30	1.20	1.30	1.53	1.18	0.94
Sig	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.004	0.000	0.000

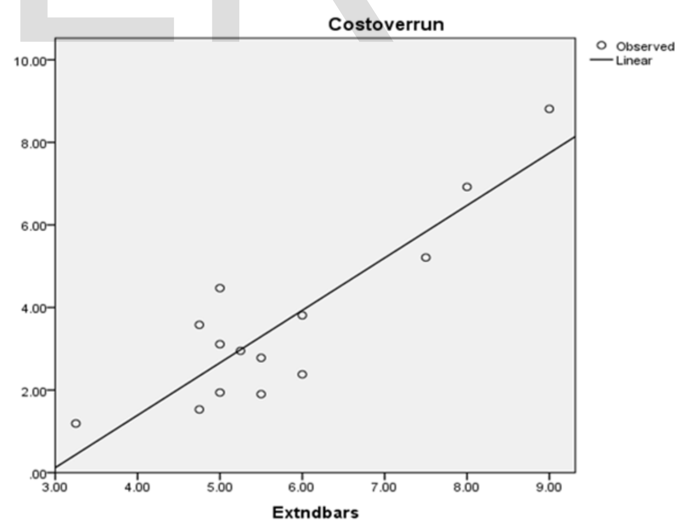

Figure 3.3 Regression line between Cost overrun and Extending bars beyond requirement

3.3 Suggestive solutions for minimizing the wastage of steel based on research findings and site observations

1. Strong discussions may be extended to finalize the occupancy types to be allocated to different floors and parts and

changes should not happen after such decisions before the structural design commences. If such changes happen, the designer may incline to enhance the safety of structure by providing greater quantity of steel.

2. Designers shall feel encouraged to adopt the reinforcement detailing provisions correctly without favoring the easiness of the bar bending process like giving uniform spacing of stirrup spacing for all beams, using same diameter of rods for all the beams etc.

3. Bar benders shall be educated and fortified not to leave excess lengths uncut, to bend 135 degree hooks for stirrups, to have careful understanding and to have better estimate of optimized procedure to cut bars from 12 m long lengths of bars as supplied.

4. Sufficient supervision by qualified engineers shall be engaged at the time of bar bending so that bar benders will feel confident of their perfection in work.

4 Conclusion

As most of the buildings under the study were private buildings, the designers, consultants and contractors were seeming to be paying attention over safety and serviceability more than the concepts of waste minimization. From the questionnaire survey it was found that the influence of cutting and bending in total cost of building was mainly due to extending bars beyond the required length. The unwanted lengths were left uncut or cutting was done with excess lengths, as the case may be, with different types of reinforcements such as in stirrups, longitudinal bars, laps and hooks. The wastage due to excess provision of steel by providing 90 degree hooks in place of 135 degree hooks for stirrups and by uncut excess lengths were found to be greater.

The influence of detailing and scheduling played a major role for increasing the effect of misuse or wastage of steel on the total cost of the project. The factors such as code provisions not followed while detailing, bar bending schedule not supplied to the bar benders and bending gain not considered while detailing and bar scheduling were found to be dominant according to questionnaire, interviews and content analysis. Wastage in steel was found to occur due to the incorrect provision of stirrup spacing, spacing of ground floor slab reinforcements, use of same diameter of rod for all the beams and due to bending gain not having considered. As far as steel is concerned, the values of percentage wastage were considered to be of low and acceptable range. Anyhow, the findings prove that there are good practices essential to be adopted while design and construction stages that were failed to be concentrated.

References

[1] S. Augustine, “Managing waste and cost in the construction industry: A case study of the road construction industry”, MBA thesis, Kwame Nkrumah Univ. of Science and Tech., Ghana, 2011.

[2] M. Baytan, “Origins and magnitude of wastes in Turkish construction industry”, M.Sc. Thesis, Middle East Technical Univ., Turkey, 2007.

[3] Bayt, https://www.bayt.com/en/specialties/q/70310/what-is-the-wastage-ratio-for-steel-bars-at-site/ 2015.

[4] R. B. Surve and S. S. Kulkarni, “Construction waste reduction – A case study”, *International Journal of Engineering Research & Technology*, vol. 2, no. 8, pp. 870-875, Aug., 2013.

[5] S.S. Al-Moghany, “Managing and minimizing construction waste in Gaza strip”, M.Sc. thesis, Islamic Univ. of Gaza, Palestine, 2006.

[6] C. Santi, “Reducing waste from cutting reinforcing steel in construction projects”, *Kasetsart J. (Nat. Sci.) 34:* http://kasetsartjournal.ku.ac.th/kuj_files/2008/A0804251444143578.pdf. 2000.

[7] A. Afshar, H. Amiri and E. Eshtehardian, “An Improved Linear Programming Model For One-Dimensional Cutting Stock Problem”, *Proc. First Int. Conf. on Construction In Developing Countries, Karachi, Pakistan,* pp. 51-56, Aug., 2008.