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Adapting Overlap Per Two Floors for Vertical Structural Members:Column and Shear Wall

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Abstract
The main aim of this study is adapting overlap per two floors for vertical structural members for column and shear wall. Since this concept is new and not applied widely in Ethiopia, the challenges, technical solution for challenges and economic differences were assessed and drawn. This study was used qualitative and quantitative research methodologies. The amounts of reinforcement bars were determined. In depth interviews, site observation, theoretical concepts, previous practical experience and secondary data were used. Purposive sampling technique was applied for selection of respondents and their working companies. In depth interviews were interpreted with respect to structural, architectural and cost perspectives. The results obtained from the purposively selected interviews, observations, theoretical concepts, practical experience and referring secondary materials for providing overlap per two floors on all columns and shear walls has no any effect on the architectural aspects of the column and shear wall. Because, overlapping per two floors for columns and shear wall does not affect the shape and cross section of the vertical elements and covered completely by concrete. Typically, the analysis of cost of reinforcement bars was done for G + 10 building. The total percentage of wastage of bars per two floors is reduced by 13.51% and 11.11% for 2.7m and 3.5m story height compared to per one floor respectively.
Keywords: Overlap, Shear wall, Column, Challenge, Solution, Cost
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1. Introduction

The current fast and dynamic economic growth of Ethiopia especially in urban area necessitates equivalent growth of building and construction sector. The sector should expand rapidly to support the overall economic development sustainable. The sector should expand rapidly to support the overall economic development sustainable [1].

The structure is composed of a number of components or elements connected together by joints or supports to fulfill the function for which it is constructed; in such a way that they can transmit the forces coming on the structure to the foundation safely without showing considerable deformation [2].

A column is a vertical structural member transmitting axial compression loads with or without moments. The cross sectional dimensions of a column are generally considerably less than its height. Column support mainly vertical loads from the floors and roof and transmit these loads to the foundation. The more general terms compression members subjected to combined axial and bending are sometimes used to refer to columns, walls, and members in concrete trusses or frames. These may be vertical, inclined, or horizontal. A column is a special case of a compression member that is vertical [3].

Shear walls are vertical elements of the horizontal force resisting system. Shear walls are constructed to counter the effects of lateral load acting on a structure. In residential construction, shear walls are straight external walls that typically form a box which provides all of the lateral support for the building. When shear walls are designed and constructed properly, and they will have the strength and stiffness to resist the horizontal forces. In building construction, a rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes. Examples are the reinforced-concrete wall or vertical truss. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and occupants; create powerful twisting (torsion) forces. These forces can literally tear (shear) a building apart. Reinforcing a frame by attaching or placing a rigid wall inside it maintains the shape of the frame and prevents rotation at the joints. Shear walls are especially important in high-rise buildings subjected to lateral wind and seismic forces [3].

Lap of bars are used for joining of main reinforcement bars by the way of sufficient overlap to create a continuation of cages to insure structural integrity of the bars. Overlap is a means of making a joint between two members end to end in construction of different structural elements. The main function of this lap is to transmit load from one bar to the other bar as well as continuity. This lap joint is used when the materials (reinforcement) is being joined is not available in the length required. All structural elements of reinforced structures whether vertical elements or horizontal elements use overlap of reinforcement either limitation on required length or structural response (bending moment, axial force, shear force, Deflection, Torsion, etc.

1.1. Overlap of reinforcement on Column and Shear wall

Longitudinal reinforcements of vertical structural elements, columns and shear walls overlap at every story height. It is means joining two parts of a column where as a column base transfers forces and moments at the lower end of a column part and to a foundation. Splice or lap on column and shear wall is not design requirement but it is a construction requirement, for easy transport of and erect on site

1.2. Statement of the Problem

Ethiopia is a developing country with a lot of large to small scale constructions going on all over the country. To satisfy the requirement of the country's infrastructure and building demand it is becoming important to adapt new techniques to have a manageable construction. It is a recent history that the cost of building in the country was very high due to the high demand put on materials. As a main construction material, reinforcing bars, has a main use of increasing the strength of concrete in buildings and as the cost of reinforcing bars is fluctuating year through year it is becoming more and more important to adapt a new trend.

Reinforced concrete overlaps, regardless of the method of their manufacturing, are usually calculated taking into account the spatial work, which means the presence of force and displacements along the direction of all three axes of coordinates in space. The forces between its individual elements are redistributed due to the work of overlaps. This is particularly noticeable when local loads act on overlaps such loads can be loads from equipment, internal partitions and premises for various purposes.

As we know, according to the revised Ethiopian building code of standard (EBCS) the length of overlap both for horizontal and vertical structural members must be fifty times diameter of the bar(50D). It includes overlaps on beam, slab, column and shear wall should satisfy the minimum lapping length. The main reason for the application of overlap is limited length (12m) of manufactured bar, for transportation and handling purpose excluding bar diameter of six (6mm).

Studies of many scientists have shown that the more spatial work is manifested, the more efficient the individual elements of the overlap are used and the more economical and reliable the overlap is. Providing overlap at any structural member results week zone at overlapped section and increase the overlapped section and increase the overall construction material cost by increasing the total amount of reinforcement required to construct a structural member.

Now a day in Ethiopia, we practices overlap of vertical structures (column, retaining wall and shear wall) per floors without consideration of floor height starting from 2.7m floor height of condominium to mezzanine floor. Generally the main goals of our research are to analyze the possible challenges for adopting overlap per two floors, provision of technical solutions for possible challenges.

2. Objectives of the research

2.1. General objective

The general objective of the research is adapting overlap per two floors for vertical structures (column and shear wall).

2.2. Specific objectives

- To analyzing the possible challenges for practicing overlap vertical structural elements per two floors.
- To propose possible technical solutions for expected challenges.
- To analyze the structural and economic advantages of overlap per to floors for vertical members.

3. Methodology

The structured interview, site observation and referring other documents were used for data collection. A total of 16 questionnaires were prepared and in depth interviews were conducted. The design and structure of questions are presented in the form of closed ended and structured. Purposive sampling technique was applied for selection of respondents and their working companies.

The sources of data for this study are both primary and secondary data. Through collection of primary information and data's, the research instruments used were from interview, site observation, theoretical concepts and previous practical experience. The secondary sources of data were obtained using relevant books, design manuals, and research papers. The target populations included under this study were contractors and consultants.

The formal interview, which consisted of five major sets of closed-ended questions, was designed to obtain data on the adaptation of rebar overlap per two floor for vertical structural element specially column. The data collection used to obtain more to know about overlapping on construction site. And also theoretical concepts supported with Etabs software, was used to determine the bending moment diagram and zones of vertical members.

Interview questions were designed in the form of a structured questionnaire. It consists of two parts: In the

first part, the interviewee was asked to give information about his/her position, experience, and project size and company grade. There are eight contracting companies registered under GC3, GC4, GC5, GC6, GC7, G10 and Consultant. In the second part, the technical knowledge on challenges and solutions were deeply interviewed.

Table 3.1. Respondents covered under this study

Stakeholders		Number of respondents	Percentage of respondents
Respondents work company (Contractors)	GC-3	1	12.5
	GC-4	1	12.5
	GC-5	1	12.5
	GC-6	1	12.5
	GC-7	1	12.5
	GC-10	2	25
Consultants		1	12.5
Educational background	Diploma	4	25
	BSc	8	50
	MSc	4	25
Respondent's Experience	0-5years	6	50
	6–10 years	9	37.5
	11-20 years	1	12.5

4. Data analysis and results

4.1. Reinforcement Steel

It is a high-strength and high cost steel bar used in the construction of reinforced concrete structures to provide additional strength. When reinforcing steel is used with concrete, the concrete is made to resist compression stress and the steel is made to resist tensile stress with or without additional compressive stress. Ethiopian building code and standards EBCS EN 1992-1-1:2014 [4], recommends the lowest value of yield strength to be 400MPa. When reinforced concrete structural elements are used, sufficient bond between the two materials must be developed to ensure that there is no relative movement between the steel bars and the surrounding concrete [4].

4.2. Reinforced Concrete Section Properties

Design of concrete sections involves determining the cross-sectional dimensions of concrete structural members and the required quantity of reinforcement. A large number of parameters have to be dealt with in design of concrete sections such as geometrical width, depth, area of reinforcement, steel strain, concrete strain and steel stress [5].

Table 4.1 Structural Elements Cross-sectional Properties

Structural element	Section name	Width (mm)	Height (mm)	Material	Reinforcement cover
Column	CL 40x40	400	400	C30 concrete	50
	CL50x50	500	500	C30 concrete	50
	CL60x60	600	600	C30 concrete	50
	CL70x70	700	700	C30 concrete	50
	CL80x80	800	800	C30 concrete	50
	CL90x90	900	900	C30 concrete	50
	CL100x100	1000	1000	C30 concrete	50
	CL110x110	1100	1100	C30 concrete	50
	CL120x120	1200	1200	C30 concrete	50
	CL130x130	1300	1300	C30 concrete	50
	CL140x140	1400	1400	C30 concrete	50
	CL150x150	1500	1500	C30 concrete	50

4.3. Shear wall

Shear wall is a structural member in a reinforced concrete framed structure to resist lateral forces such as wind forces. Shear walls are generally used in high-rise buildings subjected to lateral wind and seismic forces. In reinforced concrete framed structures the effects of wind forces increase in significance as the structure increases in height [6].

4.4. Reinforcement bar overlap

Lapping means overlapping of two bars side by side to achieve required design length. At which two bars of a

column are spliced or overlapped in order to maintain the continuity of the bars throughout the length of column. This method of overlapping two reinforcement bars facilitates the secure transfer of loads from one member to another.

4.5. Data Analysis

The interview questions were focused on professional perception, practical experience, expected challenges and technical solutions. Whole creative process in architectural and structural work is making decisions aimed at satisfying client needs interims of intended service and cost margin. Design is the art of making decisions and their logic is defended by the use of proper arguments between the professional of the construction industry. The analysis and the result of our research are based on the basic requirements of any civil engineering works. As basic requirements of design and construction any civil engineering structure should be structurally stable, economically effective and architecturally feasible. This study was analyzed and discussed according to these three pillars.

Contractors and Consultants were explained briefly in depth depend on their theoretical concepts and experience on providing overlap per floor. They were also told us the challenges and practical solution on providing overlap per two floor based on their experience on providing per floor. The challenges are construction methodology/procedures/ and absence of well-equipped and skilled man power. From the interviewed responses, the technical solution should be use construction technologies and machines, well trained daily laborers and good communication in between client, contractor and consultants.

4.5.1. Integration of structural and Architectural aspects

The structural system is one of the most important architectural and structural Components in architecture. This system usually functions parallel to other systems and together they create the whole architectural creation. During the planning and design process the architectural designer is the main entity responsible for the view of the project, taking into account many aspects of design and construction.

The aesthetics of any buildings are mainly depends on the Cross-sectional shape, Structural components, Geometric relations and the materials used for construction. Providing overlap per two floors on all columns and shear walls has no any effect on the architectural aspects of the column and shear wall. Overlapping per two floors for columns and shear wall does not affect the shape and cross section of the vertical elements. Since the reinforcement of column is structural material and covered completely by concrete. It is a high-strength and high cost steel bar used in concrete construction (e.g., in a beam, shear wall, column, slab) to provide additional strength.

Architecturally, the geometrical cross section of both vertical members does not affected due to overlapping. Whether the overlap of column and shear wall is per floor or per two floors the longitudinal reinforcement is covered completely by concrete.

Overlap of main bars per floor affects the member and results many structural defect on reinforcement.

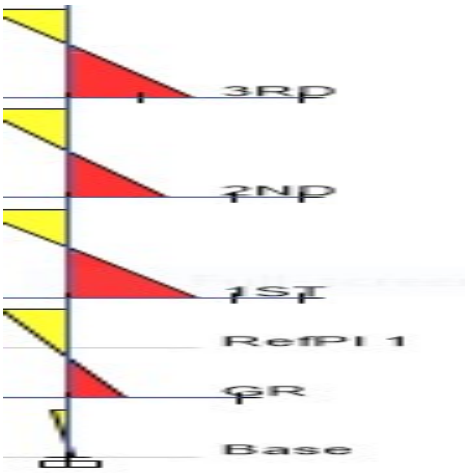
- The strength and the stiffness continuity of the reinforcement is reduced cutting and lapping repetition of per floor of column and shear wall.
- The section of the vertical member where lapping is provided, affects the mode of failure by increase the percentage of reinforcement.
- Due to poor workmanship quality and supervision many lap lengths are below the minimum lap length requirement.
- Most bonding of the top and bottom bar is achieved by black wire, results week bonding.
- The load comes from the top bar does not transfer effectively.
- The lapping zone is on zone- A (zone with maximum moment) of the members and its stiffness is affected by lap.

In construction of building, we have adopting and providing overlap of reinforcement per each story. During overlapping of reinforcement, it should be considered the following factors which affect the structural stability of column and shear wall.

- ✓ Quality of workmanship
- ✓ Reduce the performance of longitudinal bar
- ✓ Improper lapping zone
- ✓ Over-reinforcement

Fig. 4.1 Typical Side (parallel) overlapping

Figure 4.2. Column zone



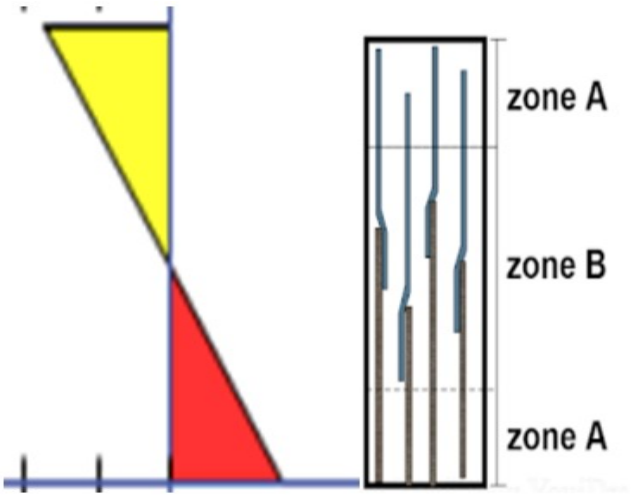


Fig. 4.3. Bending moment diagram Fig. 4.4. Bending moment diagram zones of vertical members

When we provide lapping in column all rebar should be lapped in section of a member which has minimum stress. For columns and shear walls the best lapping zone is zone-B because at this section column and shear wall has minimum moment. If the length of the column is L, then the L/4 length from the top and bottom of the column is categorized as tension zone of column, lapping should be avoided.

Fig. 4.5. Improper lapping zones observed during site over survey

4.5.2. Cost Analysis

The cost of construction includes costs of material, labor and cost of equipment's used for execution different site work. From the above listed costs of construction materials covers 45%-75% of the total cost of the construction. From all construction materials the cost of reinforcement is maximum. While we provide overlap we use black wire for proper bonding between the top and bottom rebar. The overlap section of the column and shear wall also has additional reinforcement (additional length of 50D) to satisfy the minimum lap length. The demand and growth of steel demand and cost in the world increase dramatically. In Ethiopia may factors affect the rebar cost, because it is imported construction material and it can affect easily by the global market environment. As a result we have to take care for reinforcement while we prepare structural detailing and construct the column, shear wall and the whole structural elements.

Figure 4.6 Steel cost price growth diagram [7]

Determination of wastage reduction of bar due to overlap typically for 2.7m floor height

Considering a typical G + 10 building to determine the wastage of reinforcement for different story height.

- Story height=2.7m
- Diameter of bar= Ø20
- Overlap length=50D= 50x20=1000mm=1m
- Number of overlap for ten story =10(if the lap on column and shear wall is per floor)
- Number of overlap for ten story=5(if the lap on column and shear wall is per two floor) = Total wastage reduction = 5x1m=5m
- Total length of reinforcement for G+10=10x2.7m=27m
- Length of reinforcement due to overlap=10x1m=10m
- = Total length of bar including overlap = 10m + 27m = 37m

Total percentage of wastage reinforcement reduced by using overlap per two floors:-

% of wastage reduction= 5m/37mX100%

= 0.135x100

= 13.51%

Table 4- 2 percentage of wastage reinforcement

Story height(m)	Percentage of wastage reduction due to overlap (%)
2.7	13.51
2.8	13.15
2.9	12.82
3.0	12.50
3.2	11.90
3.5	11.11

4.5.3. Challenges and technical solutions of overlapping per two floor

Erecting and placing of main bars in shear wall and columns are challenging. But, the stability of the main bars can be achieved by closely spaced bracing and lateral support. Construction duration for erection of longitudinal bar per two floors is more challenging and time taking than one floor. It needs additional bracing system new construction methodology for proper placement of rebar's of column and shear wall. For the top floor reinforcement construction will be fast, because the main bars are construction while we erect bottom bars.

Reinforcement erection, due to its relative maximum length, placing the bare is not an easy task. It needs extra lateral support to keep the bar on its location. For two floor overlapped columns and shear walls, concert casting can be affected by drop height and vibration. According to IS 456:2000 [4], the maximum permissible free fall of concrete to avoid segregation is 1.5 but per two floors overlapped columns and shear walls, the free fall height is greater than 1.5m. The placing of stirrups will be time taking due to large length of main bars if the main bars are erected before stirrup is provided.

Technical solutions for challenges of overlapping per two floors

The stability of the main bars can be achieved by closely spaced bracing and lateral support. This can be archived by wood or steel material. The free fall height of the concrete and vibration of concrete can be avoided by creating small clear space for concerting and vibrators. This can be archived by cutting some main bars of column and shear wall. The problem for provision of stirrup can be avoided by placing the stirrups on the starter bar before placing the main bars.

So, Providing overlap per floor for vertical member increase the demand of reinforcement by 25% without any structural and architectural reason. The time wasted during erection of longitudinal bar is balanced by next floor time demand for erection and supervision of reinforcement.

5. Conclusion and Recommendation

5.1. Conclusion

The performance and effect of column and shear wall per floor overlap is investigated using site visit and practical experience of professionals on the construction industry. The challenges and the advantages of adapting per two floor overlap are interpreted in order to draw the following conclusions and recommendations.

Using overlap per two floors for columns and shear wall reduce the demand and cost of reinforcement by 13.51% and 11.11% for story height 2.7m and 3.5m respectively. The number of overlap is reduced by half and it results the cost of black wire reduced by 50%. Overlapping errors related to workmanship quality is reduced by half. Structural failure risk of columns and shear wall due to poor overlap is reduced by 50%. The responsibility of supervisors for supervisors of vertical members overlap is reduced. Week zones of developed due to splice is controlled effectively. The risk of over reinforcement and sudden failure of overlapping section is reduced half of its possibility of failure. The performance of longitudinal bar is increased by fifty percent.

5.2. Recommendation

The following recommendations are drawn

- Since adapting overlap of longitudinal bar of column and shear wall per two floors is a new concept for our country construction culture, it needs some modification of design and construction method for both vertical members.
- Site engineers and supervisors should work close to labors and technical solutions to reduce the practical challenges during erection of reinforcement and concreting.
- This study will initiate and open doors for further study on this issue.

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