The Influence of Concrete Cover to Protect Reinforcing Bar on Load Carrying Capacity of Floor Slab

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Abstract

Monolithic reinforced concrete building frame becomes prevailing structural design choice in the last ten years in Mongolia. But it is observed from the study that slabs in those buildings experience cracking problems. Commonly think that these cracks are due to shrinking effects of concrete and seriousness of them is underestimated mainly from structural point of view. Even that they are serious durability issues of the structure and further of the building. In this paper the study of cracks developed in the cast-in-place reinforced concrete slabs, their possible sources and negative impacts like structural failure is provided. Two kinds of cracks for monolithic floor slab are occurred for several buildings. One begins from the upper part of floor slab which is connected to beam along floor beam. Others form in lower part of the floor beam and in the middle. These cracks are caused by reinforcement position changed for floor slab during construction. When reinforcement position for floor slab is changed by few millimeters, load carrying capacity of the floor slab is decreased, as shown in LIRA-9.4 program structural analysis.

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Key words: structure, moment, diagnosis, reinforced concrete structures, cracking

1. Introduction

Although it is considered that causes of cracking in reinforced concrete structures caused by totally 24 factors, but it can be classified into 3 groups: structural, non structural and due to fire load.

1.1. Non-Structural Cracking

There are many reasons for the development of non structural crackings in the plastic stage of freshly cast concrete.
The development of two kinds of shriveling cracks is more popular in Mongolian dry climate. First, shrinkage cracking, many studies of it commonly agree on that they are due to moisture evaporation from horizontal surface of concrete to ambient air. When the evaporation speed from surface is higher than that of the raising speed of vapor inside of the concrete, plastic shrinkage forms and cracking starts. It depends on concrete temperature, ambient temperature, relative air humidity, sun and wind effect, vapor speed within concrete mixture and water cement ration and so on, but it is truly not well investigated so far. Second, drying cracking during concrete hardening. This type of cracking is different from the shrinkage crack that mentioned above. When all concrete setting takes place and hardening begins dry crackings possibly start to form.

Another type of non structural cracking is due to reinforcement corrosion lately takes more attention on itself.

1.2. Structural Cracking

Structural cracking has an influence on load carrying capacity of the structure. Such cracks greatly decrease a structural stability and safety factors. These cracks may even lead to possible failure of structures and to accident condition in construction. Followings are some possible causes of structural cracking: design failure, change of serviceability, increase of design load, poor quality material used, mistake of construction technology, explosion, impact load, etc.

1.3. Cracks Due to Fire Load

Cracks due to fire load can be considered as both structural and non structural. Careful investigation of crack form, pattern and size is significant to the determination of its cause. It is important to check crack position in a member, its pattern and direction (vertical, horizontal and inclined) against positions of working reinforcement is very important. Moreover, the measurement of concrete cover thickness is necessary. If cause of crack cannot be determined, structural design and reinforcement scheme, technical condition are examined thoroughly.

2. Objective of the study

It is studied and evaluated the cracking problem of floor slab of basement floor and balcony slabs of 3rd and 4th floor of a 4 story newly built (2010) private housing building of size 24x15m located in 18th khoroo, Bayangol district, Ulaanbaatar city.

3. Deformation of reinforced concrete structures and causes

3.1 The Status of the Studied Structure

It is observed that crackings developed in the upper part or tension zone of reinforced concrete floor slab along beam of basement of axes, A-B-3-4, B-C-4-3. Crackings formed also in the upper part of balcony slab along beam of axis A-2-3, in the 3rd and 4th floors. The size and position of these cracks are shown in Table 1 and Figures 1. According to Mongolian Building Code “BNdD 2.03.01-90 Concrete and reinforced concrete structures” crack width of reinforced concrete structures is limited to 0.3mm. But in our studied structural elements crack width is larger than this specified value of 0.3mm.
Table 1. Cracks size

| Floor | Structure | Axis      | Crack Number | Length, mm | Width, mm | Note |
|-------|-----------|-----------|--------------|------------|-----------|------|
| 0     | Floor slab| A-B-3-4   | 3            | 4250       | 0,4       |      |
| 0     | Floor slab| B-C-3-4   | 8            | 6000       | 0,5       |      |
| 3     | Balcony   | 2-3-A     | 8            | 6000       | 1,5       |      |
| 4     | Balcony   | 2-3-A     | 8            | 6000       | 1,5       |      |

3.2 Measurement of deformation

The deformation of reinforced concrete floor slab of basement floor in axes of A-B-3-4, B-C-3-4 and balcony slab of axis A-2-3 in the 3rd and 4th floors are measured by Self leveling Contractor Grade Laser Level instrument and results are shown in Table 2. According to Building Code, permissible value of floor slab deflection is 24 mm, but some of our measured data in basement floor is larger than that (B-C-3-4 axis floor, A-B-3-4 axis floor).

The possible cause of cracking in reinforced concrete floor slab is concrete strength of reinforced concrete structures. But from our study concrete strength for framed structure was C25 which satisfies design specifications. Thus it is assumed that the crack doesn’t depend on concrete strength. Next possible cause is reinforcement. Thus concrete cover thickness of rebars are checked using instrument “Profoscope”. Result is given in Table 3.

Concrete cover thickness of floor slab is 15 mm as specified in the design, but in reality it is from 60 to 85 mm. So no reinforcement for tension of floor slab near beam and reinforcement size to receive moment became smaller. In this way, design scheme of balcony and floor slab is changed (Figure 3).

Figure 1. Cracking position and size of the slab
Thus the cracks in the upper part of floor slab axes A-B-3-4 and B-C-4-3 of basement floor and balcony slab along beam axis A-2-3 of 3rd and 4th floors started due to this position displacement of rebars.

Table 2. Deflection of floor slab

| Floor | Structures | Axis       | Deflection, mm | Note |
|-------|------------|------------|----------------|------|
| 0     | Floor slab | A-B-3-4    | 22,5           |      |
| 0     | Floor slab | B-C-3-4    | 32,5           |      |
| 3     | Balcony    | 2-3-A      | 6,5            |      |
| 4     | Balcony    | 2-3-A      | 20,5           |      |

Table 3. Concrete cover thickness to protect reinforcement for reinforced concrete floor slab

| Floor | Structures | Axis       | Concrete cover thickness, mm | Note |
|-------|------------|------------|------------------------------|------|
| 0     | Floor slab | A-B-3-4    | 80                           |      |
| 0     | Floor slab | B-C-3-4    | 75                           |      |
| 3     | Balcony    | 2-3-A      | 60                           |      |
| 4     | Balcony    | 2-3-A      | 85                           |      |

3.3 Change in the Original Design Scheme of Reinforced Concrete Floor Slab

Cracks in tension zone of the reinforced concrete floor slab of axes A-B-3-4 and B-C-4-3 of basement floor started because of the alteration of the original design scheme (Figure 3). As shown in Figure 2, in the original design scheme of the floor slab; floor slab is connected with beam by rigid constraint. However, longitudinal cracks developed on the floor slab along the edge of the beam due to downward set rebars of the upper layer the connection of slab and beam became hingid joint as shown in Figure 3. For the hinged support a moment of mid point for the floor slab span is larger than that of rigid constraint (Figure 3). For this reason, cracks developed in the lower part (tension zone) of the reinforced concrete floor slab for basement, A-B-3-4 and B-C-4-3 axis.
3.4. Change of the load carrying capacity due to changed thickness of concrete cover

When concrete cover thickness of monolithic floor slab of 6x6 m of span and space, 150 mm thick is changed from 0.5 to 5 cm, then the possible changes of its load carrying capacity (support moment) is estimated by using LIRA-9.4 program and results are shown in Table 4.

Table 4. Load carrying capacity of floor slab as effected by concrete cover thickness for slab

| No. | Cover thickness, mm | Support moment, kNm | Span moment, kNm | Decrease in load carrying capacity, % |
|-----|---------------------|---------------------|-----------------|--------------------------------------|
| 1   | 20                  | 0.88                | 3.9             | 0                                    |
| 2   | 25                  | 0.82                | 4.1             | 7                                    |
| 3   | 30                  | 0.77                | 4.3             | 12.5                                 |
| 4   | 35                  | 0.72                | 4.7             | 18.8                                 |
| 5   | 40                  | 0.69                | 4.8             | 21.6                                 |
| 6   | 45                  | 0.65                | 5.2             | 26.2                                 |
| 7   | 50                  | 0.59                | 5.5             | 33                                   |
| 8   | 55                  | 0.51                | 5.7             | 42.1                                 |
| 9   | 60                  | 0.49                | 6.2             | 44.4                                 |
| 10  | 65                  | 0.45                | 6.6             | 48.9                                 |
| 11  | 70                  | 0                   | 7.1             | 100                                  |

As shown in Table 4, if concrete cover thickness is changed by 10 mm and 20 mm then its bearing capacity will be decreased by 12.5 percent and 21.6 percent respectively. But if cover thickness is changed by 50 mm, then it is possibly collapse.

Fig. 4. Design modelling scheme of slab

4. Conclusions

1. Thorough checking of reinforcement location and depth of concrete cover is necessary before casting of concrete.
2. Cracks developed after concrete works must be examined and studied in each case.
3. If cracking is structural in reinforced concrete slab of monolithic frame then in this case the checking of concrete cover depth should be provided.

Fig. 5. Bending moment diagram of slab with concrete cover of $\rho=2$ $\text{m}$ is $\Phi=3.9$ $\text{M}=0.88$

Fig. 6. Bending moment diagram of slab with concrete cover of $\rho=7$ $\text{m}$ is $\Phi=7.1$ $\text{M}=0$

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