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Measuring the Resistance Capacity of an Anchoring Concrete Weight Body for Tower Crane

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Abstract: This study set out to find a practical method to secure the stability of a supporting structure in cases of tower crane or large formwork in which the use of a reinforcing anchor body is inevitable. The parameters of reinforced concrete reinforcement were determined as the diameter, type of anchor and embedded depth. The concrete compressive strengths used in this experiment were 21, 24 and 27 MPa which are generally used on construction sites. Reinforcing steel bars of D13, D16 and D22 diameters were also used and the strengths and failure modes were investigated in these different conditions. The following conclusions were drawn from the experimental results. The experimental results for the D22 reinforcing bar showed that anchors can be designed and fabricated in a balanced manner when the ratio of the reinforcing bars to the cross-sectional area of the concrete is maintained above 0.95%. The increase in the cross-sectional area of reinforced concrete as compared with the surface area of reinforced concrete is about 2 or 3 times. This suggests that in order to increase the tensile strength of reinforcing bars, a method to optimize the landfill depth rather than the diameter of the reinforcing steel bar can easily be applied on construction sites.

Key words: Reinforcing anchor, supporting structure, concrete compressive strength, embedded rebar, steel, cross-sectional

INTRODUCTION

There can be big problems if collapse accidents occur on construction sites. It is believed that concrete body anchoring and the anchor itself are critical to the prevention of this type of accident. This study set out to find reasonable method to ensure a certain stability in conditions in which work is performed without steel beam support or any other type of support, i.e., in cases of unfixed tower cranes with free standing height or without wall bracing. Therefore, we sought to identify a way to deal with situations in which only guy wire can be used for support. This study also sought to find practical countermeasures against some problems to use based on one's own judgment and without any structural stability review, whether embedding an anchor into a concrete body or fixing it to another structure. The rebar diameter, embedded length, hooking or non-hooking and concrete compressive strength were the variables evaluated to measure the anchor capacity. Equipment was made with the same materials used on construction sites. Additionally, practical countermeasures were identified to be applied to the design and construction of concrete anchoring weights needed by contractors after comparing the tower crane-supporting capacity with the test results for the RC anchor body. Concrete strengths of 21, 24 and 27 MPa are commonly used and applied on construction sites. This is the main reason why the researchers used these strengths to measure all the variables in the study. A guy-wiring method, mostly with a 60° slope, should be adopted to support tower cranes operated with a certain load on construction site. The 4 guying system is mostly used in the field, meaning that one guy-wiring anchor should eventually be loaded with the total tower crane operation load, following a domino fracture case. This means that construction contractors should incorporate this structural concept into the tower crane design and installation (Lee *et al*., 2009; Hyung, 2009; Bum, 2015; Nam, 2014; Tae, 2016; Yol, 2017).

MATERIALS AND METHODS

Material properties: The test results are presented in Table 1:

- Water tank temperature: 20±2°C
- Constant curing in water tank during winter season
- Three sets of molds of each variable were cured in the open yard by the building under construction

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Table 1: Concrete compressive strength

				Test results at 28 days of age (MPa)			
Curing	Design strength (MPa)	Size (cm)	Curing period	1	2	3	Average
Water tank	21	D10×D20	28 Work	35.5	35.6	36.3	35.8
	24			38.4	38.1	39.5	38.6
	27			44.6	43.3	43.2	43.7
Open yard		D10×D20	28 Work				
	21			31.8	31.4	31.6	31.6
	24			34.1	35.2	35.0	34.8
	27			38.6	39.2	38.0	38.6

Table 2: Diagram of test pieces for each variable (6)

Test pieces (hook, diameter, concrete strength)	Maximum load averaged with 3 for each variable
H-D13-21	75
H-D16-21	128
H-D22-21	270
H-D13-24	82
H-D16-24	107
H-D22-24	270
H-D13-27	70
H-D16-27	130
H-D22-27	230

Tests of the rebar tensile strength for each diameter (D13, D16 and D22 SD 500) were performed in accordance with the 2016 KS D 3504 of the Korea National Construction Material Laboratory. The averaged results were found to be 624 N/mm^2 for D13, 646 N/mm^2 for D16 and 671 N/mm^2 for D22.

Test plan: Anchors embedded into a heavy concrete body in the ground are supposed to be connected to a guy wire at 60° to resist the operation load. This can generally be applied to a vertical body with a P sin of 60°.

As shown in Table 2, a total of 54 test pieces with a size of 20*20*47 cm were made to consider 18 variables with 3 test pieces per variable. The above tests were performed using this model of P sin 60° of guy wire load to be supported as previously mentioned.

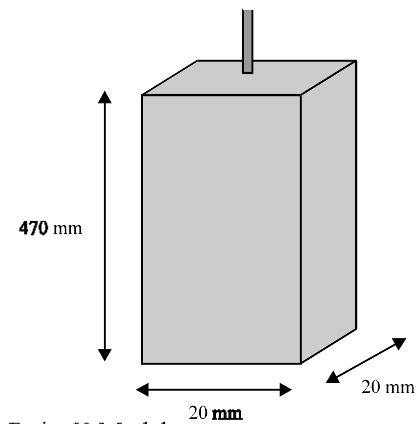

Fig. 1: P sin 60 Model

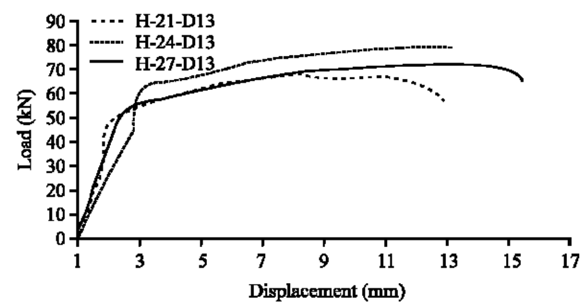

Fig. 2: Load displacement curve, D13, hook condition

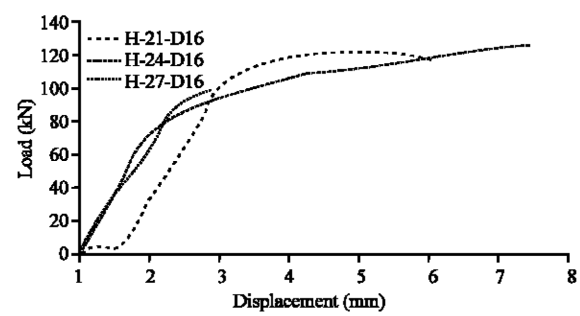

Fig. 3: Load displacement curve, D16, hook condition

RESULTS AND DISCUSSION

The test pieces varied in rebar diameter (D13, D16 and D22), embedded depth (45, 37 and 35 cm) and concrete strength (21, 24 and 27 MPa) as shown in Fig. 1-3.

Below are comparisons for different concrete compressive strengths (21, 24 and 27MPa). It is expected that a concrete strength of 27 MPa should have the most displacement as shown on the load-displacement curve for a D13 rebar.

It was found that a D13 rebar of anchor concrete could be fractured first, even if the anchor concrete strength was much higher. This means that the resistant capacity of the D13 rebar disappeared first with a strength of 27 MPa. This is the reason why a rebar is not balanced with a comparatively high concrete compressive strength of 27 MPa as shown in Fig. 3.

The higher the concrete strength, the more the elastic properties decreased in the case of a D13 rebar. It was found to be fractured at 2.3 mm of displacement under 27 MPa, 7.5 mm under 24 MPa and 6 mm under 21 MPa as shown in Fig. 3.

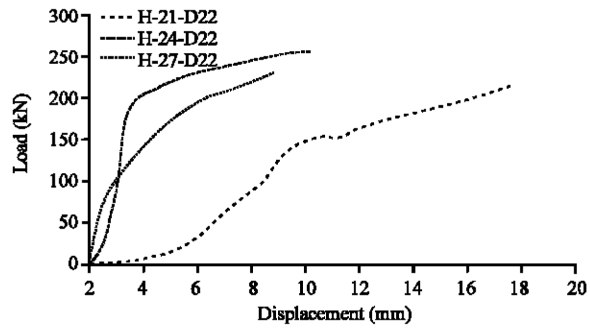

Fig. 4: Load displacement curve, D22, hook condition

It is shown that the anchor concrete body under 27 and 24 Mpa was first fractured when a D22 was embedded as an anchor. It is also shown that under a concrete strength of 21 MPa, it was fractured with a displacement of 8.0 mm and at a displacement of 8.0 mm under a concrete 24 MPa strength when a D16 rebar was embedded. Moreover, it was found that a concrete strength of 21 MPa consistently showed an 18 mm displacement and the rebar was first fractured at an 18 mm displacement point as shown in Fig. 4.

Analysis: The maximum resistance capacity of an SD 500 rebar with a maximum error within 8.7% averaged 2.9%. The test results were found to be significant.

A D13 rebar with a study of 20*20*(400 cm^2) was fractured before the concrete without any range. Eventually, it was verified that the guy wire function was damaged. This means that the anchor body capacity could be fractured independently from the anchorage type (hooked or non-hooked) at a maximum capacity of 75-79 kN in the case of an embedded depth of 37-45 cm.

It was also shown that the anchoring capacity of the anchor body failed due to the earlier facture of the rebar than of a concrete body with gradual cracking of the concrete study. The rebar capacity was found to range between 122 and 128 kN when embedded into a 35-45 cm depth.

Finally, for a D22 rebar with an embedded depth of 45 cm, the concrete and rebar had almost the same fracture point, meaning that a balanced fracture was made. The average maximum capacity of 259 kN is over the capacity of the original standard tensile strength (240 kN) of a SD 500 rebar in accordance with the KS regulations. It is also, recommended that an anchorage depth of 45 cm△ should be used in order to load the advanced ductility fracture of the rebar in consideration of the possible failure of the structural function due to a concrete brittleness fracture.

Additionally when an anchoring depth of 35 cm in the concrete body was used for a D 22, the concrete body was fractured first independently from the concrete compressive strength differences. This showed that the concrete was fractured before the rebar.

CONCLUSION

The following conclusions were drawn from the experimental results: the experimental results for the D 22 reinforcing bar showed that anchors can be designed and fabricated in a balanced manner when the ratio of the reinforcing bars to the cross-sectional area of the concrete is maintained above 0.95%.

When the minimum depth of embedding of reinforcing bars is ensured, the magnitude of the bonding force is related to the diameter of the reinforcing bar, the concrete strength and the hooking order. This should be considered when making reinforced concrete anchors.

The increase in the cross-sectional area of reinforced concrete as compared with the surface area of reinforced concrete is about 2 or 3 times. This suggests that in order to increase the tensile strength of reinforcing bars, a method to optimize the landfill depth rather than the diameter of the reinforcing steel bar can easily be applied on construction sites.

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