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Shear strength of epoxy anchors embedded into low strength concrete

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HIGHLIGHTS

- Cyclic shear tests were conducted on anchors embedded to low strength concrete.
- The obtained results indicate that increasing the anchor diameter have decreased the shear strength.
- A decrease in shear capacity was observed for lower concrete strengths.
- A reduction factor is introduced depending on the bar diameter and concrete strength.
- Establishing an upper limit for the anchor bar diameter in the related standards is proposed.

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ABSTRACT

Chemical anchors are getting more frequently used to connect structural elements. The studies regarding the chemical anchors embedded in low strength concrete are very limited in the literature. However, the compressive strength of the concrete may be 10 MPa or lower in many strengthening applications. Steel bars having 12, 16 and 20 mm diameters have been selected as the anchor rod in this study. They have been embedded in to concrete blocks with 5.9 and 10.9 MPa compressive strength. Solvent-free epoxy based three component chemical adhesive has been used for the connection between concrete and anchor bar. The depth of holes is 10, 15 and 20 times that of the anchor diameter. The anchors have been embedded such that they are sufficiently away from the free edge so as not to cause any concrete failure. The load–displacement cycles of all anchors have been obtained by reversed cyclic tests with incremental displacement. The obtained results indicate that increasing the anchor diameter have decreased the shear strength. Even though the anchor damage has been caused by steel failure, a decrease in shear capacity was observed with the lower strength concrete.

1. Introduction

Anchors that are used to provide the connection between two different elements can be categorized under two categories as cast-in-place and post-installed anchorages. Post-installed anchorages could be manufactured using different methods such as mechanical, grout or chemical. The behavior of cast-in-place anchors [1] and post-installed mechanical anchors [2] have been studied considerably well in previous studies conducted in the past years. The design of cast-in-place anchorages [3] and mechanical anchorages [4] has been consigned to a reliable procedure as a result of these studies. Although the use of chemical adhesives in the construction sector goes back to late 1960s [5], the studies on the use of chemical anchors especially used for strengthening applications are relatively recent and a standard for specifying the design principles of such anchors has not yet been established, also under the influence of wide variety of materials [6].

Chemical anchors are embedded in the holes set up in the hardened concrete. The diameter of the drilled hole is at most 50% larger than that of the bar diameter [2]. Chemical adhesives are among the best solutions providing the bonding forces between the concrete and the steel [7]. Chemical anchors have begun to be widely used starting in the 1990s with the development of high resistance adhesives of polyester, vinylester and epoxy type [8,9]. Nowadays, many products are available in the market in terms of chemical adhesives. However, the bonding resistance of epoxy type products is usually higher than that of esther based products [10].

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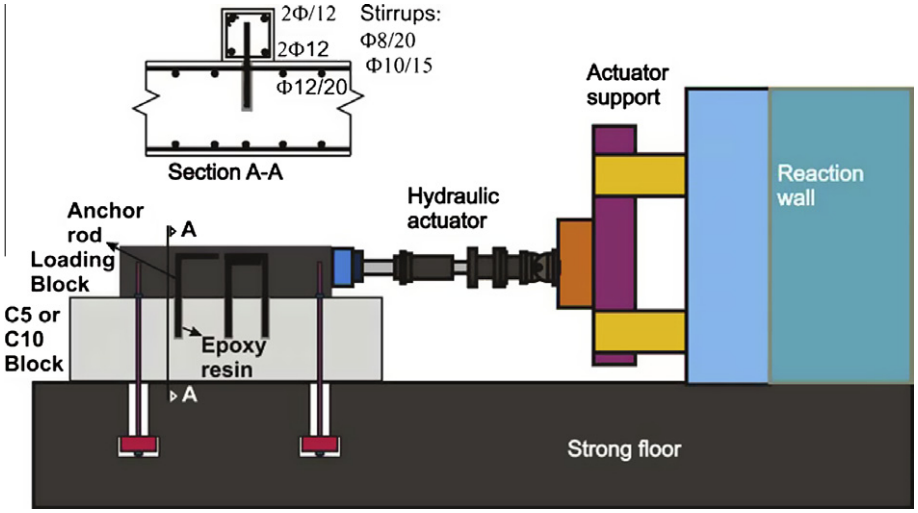

Fig. 1. Test setup and detailing of specimens.

Table 1
Properties of the test specimens.

Specimen name	Mean concrete compressive strength (MPa)	Anchor diameter (mm)	Embedment depth (mm)
C5D12L12	5.9	12	120
C5D12L18	5.9	12	180
C5D12L24	5.9	12	240
C5D16L16	5.9	16	160
C5D16L24	5.9	16	240
C5D16L32	5.9	16	320
C5D20L20	5.9	20	200
C5D20L30	5.9	20	300
C5D20L40	5.9	20	400
C10D12L12	10.9	12	120
C10D12L18	10.9	12	180
C10D12L24	10.9	12	240
C10D16L16	10.9	16	160
C10D16L24	10.9	16	240
C10D16L32	10.9	16	320
C10D20L20	10.9	20	200
C10D20L30	10.9	20	300
C10D20L40	10.9	20	400

Table 2
Concrete mixture (by weight).

Material (kg/m^3)	C5	C10	Loading block
0–5 Aggregate	1300	1235	1065
5–15 Aggregate	390	400	295
15–22 Aggregate	390	427	560
cement	100	185	310
Water	175	150	168
Additive (super fluidizer)	0.8	1.5	4.5

Many parameters such as the cleanness of the drilled hole, the method of drilling, the humidity level of the concrete and temperature may affect the bond strength in addition to the type of adhesive [2].

The first studies on chemical anchors go back to the early 1980s [11]. Most parts of those studies are based on experimental studies for determining the tensile strength of the anchors. The effect of different factors on the anchor tensile strength has been investigated in those studies. Factors such as the adhesive thickness, the type of filler material added to the adhesive [12], the embedment depth [8], the anchorage diameter [13,14], the steel

Table 3
Uniaxial strength of concrete and steel.

Material		Strength type (yield/tensile/compressive)	Mean strength (MPa)
Base concrete	C5	f_{c28}	5.9
	C10	f_{c28}	10.9
Loading block		f_{c28}	36.4
Anchor bars	Φ12	f_y	543
		f_u	628
	Φ16	f_y	534
		f_u	633
	Φ20	f_y	536
		f_u	657

f_c: compressive strength; f_y: yield strength; f_u: ultimate strength.

Table 4
Mix proportions and mechanical properties of the chemical adhesive.

Number of component	3
Mixture ratio	A/B/C
Weight	30/20/50
Volumetric	30/20/50
Mixture density (g/cm^3, 20 °C)	1.70–1.90
Pot life (min, 23 °C)	50–70
Tensile strength (N/mm^2)	16.9
Compressive strength (N/mm^2)	69.5
Modulus of elasticity (N/mm^2)	4500

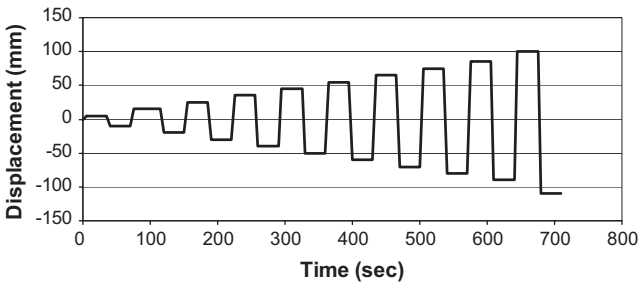

Fig. 2. Displacement profile applied to specimens.

resistance [15], the edge distance [16] and the distance between the anchorages [17] have been investigated in parts of these studies. In some studies, it has been observed that the concrete