Design of Post Installed chemical anchorage for Concrete – Steel connection

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Abstract : This paper focuses on the behavior of chemical fasteners for concrete and steel connections. Detailed behavior of the chemical anchorage and designing part of the chemical anchorage has been studied along with the installation process for better understanding. Manual and software design has been done and compared along with the installation process for better knowledge. The goal of this research paper is to do an overall study about chemical anchoring system regarding designing procedure for the cracked concrete. Different European codes and approvals are referred and used for designing the chemical anchorage. Design is done for the Hilti product – HIT-V + HIT RE 500 V3 using software Hilti Profis-Anchors. Evaluation of Service Report is done by ETA 16/0143. Design method is ETAG BOND (EOTA TR 029) + Seismic (EOTA TR 045).

IndexTerms - ***Bonded fasteners, Product assessment, Profis – design, structural connections, Technical Assessment Data (TDA)***.

I. INTRODUCTION

In most of the developing countries as well as in the developed countries in the world, the buildings and structures are aging and needs proper maintenance and also a repairing work periodically. Also, the majority of existing constructions are on the position of lack of current knowledge and design codes. Also population is increasing day by day this implies increase in need of shelter. So, Future expansion for existing structures becomes prominent motto instead of building new structures. In practice, most of the connections between reinforced concrete element as well as for steel-concrete joints are carried out by bonding deformed reinforcing bars or by anchors with adhesive mortar in holes drilled into existing concrete problem of the structural deficiency of existing constructions is especially in seismic regions, as, even there, seismic design of structures is relatively recent. The cost of demolition, repairing and reconstructing structurally deficient constructions are little prohibitive; also, they comprise a substantial waste of natural resources and energy. Therefore, the need of structural retrofitting is increasing widely throughout the world.
Anchor bolts are used to connect structural as well as non-structural elements to the concrete. The connection is made by an assembling of different components like anchor bolts or fasteners, steel plates, and stiffeners. Anchor bolts transfer different types of load such as tension forces, shear forces or in combination. A connection between structural elements can be represented by steel column attached to reinforced concrete foundation.

II. OBJECTIVES

1. Design of post installed chemical fastening systems for concrete structures using product HIT-V + HIT RE 500 V3/HIT-HY 200.
2. To design chemical anchorage by Hilti Profis- Anchors software.
3. To design chemical anchorage manually.
4. Installation of the chemical anchorage.

III. MATERIALS AND TOOLS USED

A. HIT-RE 500 V3:
Base materials: Concrete (cracked), Concrete (un-cracked), some types of natural stone
Base material condition: Dry, Submerged, Water-filled, Wet
Approvals / test reports: BZS/shock, DIBt, ETA, Fire, ICC-ES report (concrete), Seismic.

2. HIT-V:

Material, corrosion: Carbon steel, zinc-plated

Base materials: Concrete (cracked), Concrete (un-cracked), Masonry (solid)

PROFIS software: Yes

IV. CONDITIONS FOR DESIGN

a) Selecting and designing the right anchors according to the right connections under the right loading conditions so no matter the location or the loading, you can be assured that your structure will have the highest level of safety we offer.

b) The following factors should be considered when designing connections using post-installed anchor:

Loading type and direction, required edge distances, anchor spacing, embedment depth and anchor length, Concrete quality and condition, Installation condition, exposure to weather, temperature fluctuations, chemicals, and fire, Importance of connection and consequences of failure.

V. AIM OF ANCHOR BOLT DESIGN

The main aim of anchor bolt design is to analyze and design an anchor bolt connection of adequate safety and serviceable level in its design life, both at a sufficiently and acceptably low probability of violating the limit states. The anchor bolt connection should fulfill its purpose of construction during the design life of a structure. Adopted method for the design is **ETAG BOND (EOTA TR 029) + Seismic (EOTA TR 045). Evaluation of Service Report is done by ETA 16/0143.** The anchor calculation is based on a rigid baseplate assumption.

VI. DESIGN OF CHEMICAL ANCHORAGE

One example is taken for design conditions- Static and Seismic. Manual and Software design is done, and compared.

Manual Design is done using European Codes, Approvals. Software design is done by Hilti- Profis Anchor. Structural connections are designed for one example.

This is done for to check difference between Manual design and software design results.

2 X 2 post – installed adhesive anchor group subjected to tension, moment and shear. Figure shows a 2 X 2 anchor group subjected to a design tension force of - 6 KN, moment of 8 KNm and a design shear force of 12 KN. Calculate design resistance in tension and shear for the case. Check utilization %. Recommended modifications can be done to make the design pass without altering the anchor or edge and spacing conditions, if required.

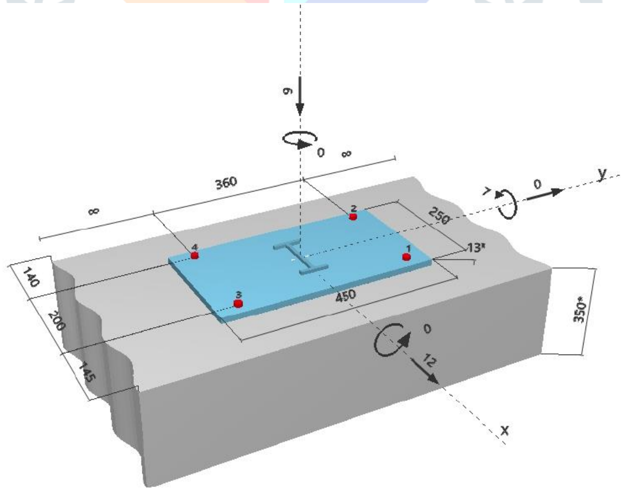

FIG 1.DIMENSIONS AND LOADS OF SLAB PANEL
(Dimensions are in KN, KNm, mm)

Table 1: Design Parameters

Concrete	
Concrete Grade	C25
Concrete condition	Cracked
Reinforcement spacing (mm)	150
Anchor Bolt	
Adhesive anchoring system: **Hilti HIT RE 500 V3 with HIT-V (8.8) M16**	
Evaluation Service Report:	ETA-16/0143
Proof: Design Method ETAG	ETAG BOND (EOTA TR 029)
Bolt8 size	M16
Nominal diameter of drill bit [d_0(mm)]	=18
Effective embedment depth [h_{ef}(mm)]	=252-Seismic =80-Static
Minimum thickness of concrete member [h_{min}(mm)=h_{ef}+2.d_0]	=284
Minimum spacing [S_{min}(mm)]	=200
Minimum edge distance [c_{min}(mm)]	=140

Design loads are 12 KN shear, -6 KN tension.

DESIGN FOR STATIC CONDITION

Table 2: The design of anchor bolt for static condition is tabulated as follows:

DESCRIPTION	**MANUAL DESIGN**	**SOFTWARE DESIGN**
A. STATIC LOAD		
1. CALCULATION FOR TENSION RESISTANCE		
DESIGN STEEL RESISTANCE ($N_{Rd,s}$)	83.733 KN	83.733 KN
UTILIZATION β_N	18.38%	19%
DESIGN PULL-OUT RESISTANCE($N_{Rd,p}$)	45.01 KN	45.038 KN
UTILIZATION β_N	68.38%	68%
DESIGN OF CONCRETE BREAKOUT RESISTANCE($N_{Rd,s}$)	36.953 KN	36.954KN
UTILIZATION β_N	83.29%	82%
DESIGN OF SPLITTTING RESISTANCE	-	-

UTILIZATION β_N	-	-
2. CALCULATION FOR SHEAR RESISTANCE		
DESIGN STEEL $(V_{Rd,s})$	50.24 KN	50.240KN
UTILIZATION (β_V)	5.97%	6%
DESIGN OF CONCRETE PRY-OUT RESISTANCE$(V_{Rd,cp})$	132.56 KN	132.565KN
UTILIZATION (β_V)	9.05 %	10%
DESIGN OF CONCRETE EDGE BREAKOUT RESISTANCE$(V_{Rd,c})$	29.626 KN	29.698KN
UTILIZATION (β_V)	40.50%	41%
3. COMBINED TENSION AND SHEAR LOADS		
$(\beta_N)^\alpha + (\beta_V)^\alpha \leq 1$	$=(30.78/36.78)^{1.5}+(12/29.676)^{1.5}=1$	=1
UTILIZATION $(\beta_{N,v})\%$	100%	100 %

DESIGN FOR SEISMIC CONDITION

Above same case is designed for seismic condition.

Table 3: The design of anchor bolt is tabulated for seismic as follows:

DESCRIPTION	MANUAL DESIGN RESULTS	SOFTWARE DESIGN RESULTS
B. SEISMIC LOAD		
1. CALCULATION FOR TENSION RESISTANCE		
DESIGN STEEL RESISTANCE$N_{Rd,s}$	83.733 KN	83.733 KN
UTILIZATION (β_N)	18.37%	19%
DESIGN PULL-OUT RESISTANCE$N_{Rd,p}$	53.25 KN	53.302 KN
UTILIZATION (β_N)	57.06%	57%
DESIGN OF CONCRETE BREAKOUT RESISTANCE$N_{Rd,s}$	55.69 KN	55.582 KN
UTILIZATION (β_N)	=54.69%	55%
2. CALCULATION FOR SHEAR RESISTANCE		

DESIGN STEEL RESISTANCE $V_{Rd,s,seis}$	27.20 KN	27.200 KN
DESIGN STEEL RESISTANCE (REDUCED) $V_{Rd,s,seis,reduced}$	25.5 KN	25.5 KN
UTILIZATION (β_V)	=11.94%	=12%
DESIGN OF CONCRETE PRY-OUT RESISTANCE	110.98 KN	110.623 KN
DESIGN OF CONCRETE PRY-OUT RESISTANCE (REDUCED) $V_{Rd,cp,seis,reduced}$	103.709 KN	103.709 KN
UTILIZATION (β_V)	=11.57 %	=12%
DESIGN OF CONCRETE EDGE BREAKOUT RESISTANCE	29.66KN	29.660 KN
DESIGN OF CONCRETE EDGE BREAKOUT RESISTANCE(REDUCED) $V_{Rd,c,seis,reduced}$	27.75 KN	27.806 KN
UTILIZATION (β_V)	=43.24 %	=44%
3. COMBINED TENSION AND SHEAR LOADS		
$(\beta_N)^1 + (\beta_V)^1 \leq 1$	=(0.570)+(0.4) =1	=1
UTILIZATION $(\beta_{N,v})\%$	100 %	100 %
REQUIRED DLS DISPLACEMENT		
TENSION LOAD		**0.50 MM**
SHEAR LOAD		**3.20 MM**

VII. INSTALLATION OF DESIGNED CHEMICAL ANCHORS

For above designed case, installation of chemical anchors is done for the same case.

Steps of installation:

1. CASTING OF SLAB PANEL ANDCUBE:

Fig: 3.Casting of slab panel

- As per the clause 6.2.5(2), EC2:EN 992-1-2004, Rough interface is required to provide sufficient cohesion in the construction joint.
- Also, roughness a surface with at least 3 mm roughness (Rt> 3 mm), achieved by ranking, exposure the aggregate or other methods giving an equivalent behaviour.

2. DRILLING OF HOLES AS SPECIFIED:

- Holes shall be drilled to a specified Depth and diameter depending on the site conditions.
- Refer Hilti manual provided. Also refer ETA-16/0143, Table B3, for diameter and depth of holes. (Diameter = 12mm, Depth = 150 mm)

Fig: 4. Drilling

3. CLEANING OF DRILLED HOLES:

- Especially for chemical anchorage, proper cleaning of drilling holes is very much required for proper bonding between anchorage and chemical.
- The holes should be blown out using compressed, oil free air.
- Extension tubes and air nozzles directing the air to the hole walls should be used, if holes are deeper than 250 mm.
- Holes shall be propped if dispensing is to be carried out later.

Fig.5. Cleaning of holes (Blowing)

Fig. 6 Brushing

4. DISPENCING OF CHEMICALS:
   - Chemical that I have chosen is HIT-RE-500.
   - Contents: (A): Epoxy Resin, Content (B): Amine hardener
   - Air bubbles should be avoided during the injection of the adhesive.
   - In order to reach the bottom of the drilled holes, mixer extension shall be used.
   - The holes should be filled with HIT to about 2/3.
   - Piston plugs ensure filling of the holes without air bubbles.

Fig 7. Ejecting chemical

5. INSERTING HIT-V RODS:

- After injecting the chemical, the M10 HIT-V rods should be inserted into the holes with a slight rotating movement. And let chemical dry.
- Ideal setting time of chemical/adhesive is 7 hours.

Fig: 8. Inserting HIT-V rods

VIII. RESULTS

A. For Example Design-

1. Static Condition:

Manual Method Results

Tension Resistance: -
1.Design steel resistance=83.73 KN
2.Design pull-out resistance=45.01KN
3.Design concrete breakout resistance=36.953KN – (Tension) Maximum Utilization – **83.29%**ForDesign concrete breakout resistance

ShearResistance: -
1.Design steel resistance=50.24KN
2.Design concrete pry-out resistance=132.56KN
3.Design concrete edge breakout resistance=29.626KN

(Shear) Maximum Utilization – **40.50%**ForDesign concrete edge breakout resistance

Combined Shear and Tension Load Resistance: -
Utilization = 100%

Software Method Results

Tension: -
1.Design steel resistance=83.733 KN
2.Design pull-out resistance=45.038 KN
3.Design concrete breakout resistance=36.954 KN
(Tension) Maximum Utilization **- 82%**

ForDesign concrete breakout resistance

Shear: -
1.Design steel resistance=50.240KN
2.Design concrete pry-out resistance=132.565KN
3. Design concrete edge breakoutresistance=29.62 KN

(Shear) Maximum Utilization **- 41%**ForDesign concrete edge breakout resistance.

Combined Shear and Tension Load Resistance: -
Utilization = 100%

B.For Example Design-

Seismic Condition:

1. Design steel resistance=83.733 KN
2. Design pull-out resistance=50.14 KN
3. Design concrete breakout resistance=55.69KN (Tension) Maximum Utilization – **60.61%**ForDesign pull-out resistance

Shear Resistance: -
1. Design steel resistance=50.24KN
2. Design concrete pry-out resistance=132.56KN
3. Design concrete edge breakout resistance=29.626KN

(Shear) Maximum Utilization – **40.50%** ForDesign concrete edge breakout resistance

Combined Shear and Tension Load Resistance: -
Utilization = 100%

IX. CONCLUSION

A. Results for Utilization (%), Design Resistance obtained using Manual Design Method and Software Design Method is similar for all cases.

B. The design concrete resistance under tensile and shear loading, combination obtained using manual and software design method satisfies the criteria. Thus, we can conclude Results obtained from the software design and manual designs are correct.

C. Software design is easy and fast. Hence, Software is an effective tool for the design of anchors. It reduces the tedious calculation and is user-friendly and effective tool for Post-Installed Anchor design.

References

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