Fine Ceramic Inserts for Precast, Prestressed Concrete Projects

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Corrosion of steel anchors in concrete can lead to anchor detachment, structural damage, and loss of strength in the component in which the anchors are embedded. Therefore, to enhance the durability of concrete structural elements that use anchors, corrosion-resistant, nonmetallic inserts such as fine ceramic inserts (FCIs) are of interest to engineers and contractors. FCIs are made of 96% alumina, a material whose composition and hardness are stable over time. Alumina is a nonmetallic, ceramic compound also known as aluminum oxide (Al_2O_3), which does not react in fresh concrete. FCIs are manufactured using a one-piece molding method, which makes the inserts consistent and relatively flawless in their quality. In addition, standard jigs are available to facilitate the installation of FCIs in formwork.

FCI Capacity

Table 1 shows the shear (thread-stripping) strength of FCIs compared with steel nuts and demonstrates that the performance of FCIs is comparable to that of steel inserts. Investigators at the University of Houston[1] evaluated the tensile strength of FCIs using the concrete cone breakout method specified in the American Concrete Institute's *Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)*.[2] FCIs have not yet been evaluated for seismic loadings.

The University of Houston study was an experimental investigation of the tensile and shear concrete breakout capacities of a single cast-in FCI. The tensile tests were performed with FCIs located at the centers and edges of concrete blocks. The shear tests were performed with inserts positioned at varying distances from the block's edge.

Test results from the University of Houston investigation show that the strength of an FCI can be reasonably evaluated using the formulas specified in ACI 318-19. The results from the 76 experimental tests exceeded the ACI prediction for the concrete cone breakout. The general failure modes for most of the tested specimens were similar to the predicted failure modes defined by ACI. The only exception was that in the shear tests, the FCI experienced high stresses at the top part of the insert, which caused the FCI to fracture.

Thus, the results from the experimental program within the scope of this work show that the use of the ACI 318-19 equation will provide a relatively conservative estimate of the concrete capacity of the FCI insert based on only unfactored capacities. Further studies and reliability analyses are needed to assess the use the ACI 318-19 factors or evaluate new factors for the FCI insert system.

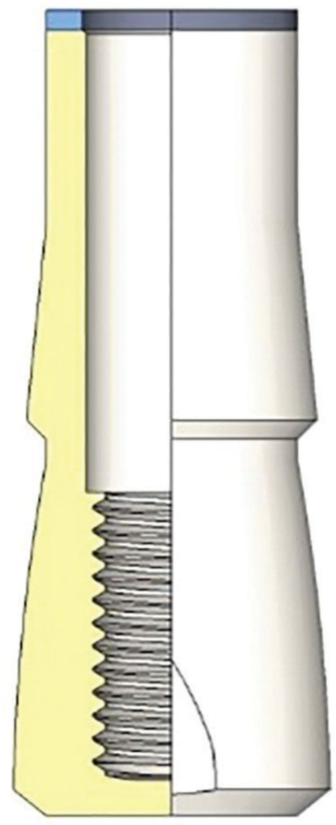


Illustration of a fine ceramic insert. All Figures: Japan Life.

Salt and Alkali Resistances

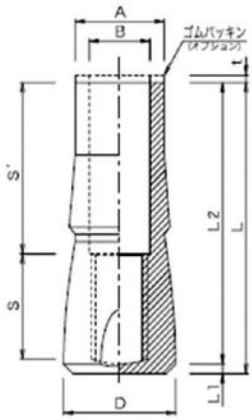
FCIs have been tested to assess their resistance to salts and alkalis. In accordance with the technical evaluation certificate "Construction Methods for

Table 1. Comparison of the shear (thread stripping) strength of a fine ceramic insert with steel nuts.

Fine ceramic insert size	Fine ceramic insert breaking load, kN	Fine ceramic insert breaking load, kip	Shear (thread-stripping) capacity of steel nut, kN	Shear (thread-stripping) capacity of steel nut, kip
M8	29.9	6.7	21.6	4.9
M10	56.5	12.7	34.2	7.7
M12	80.1	18.0	51.4	11.6
M16	130.9	29.4	95.8	21.5
M20	216.6	48.7	154.4	34.7
M22	289.0	65.0	190.9	42.9
M24	342.6	77.0	222.4	50.0

Note: The specified shear capacity values for steel nuts are based on the Japanese Industrial Standard JIS B1052, *Mechanical Properties of Steel Nuts*, strength category 5 (nuts, coarse thread).

FCI



Standard Dimensions

in mm

Product's Code (FCI)	Screw	FCI (Main body)							
		L	L2	L2	D	A	B	S	S'
M10N x 43	M10	43	2	41	22	17	11	18.5	23.5
M12N x 60	M12	59.5	2	57.5	24	19	13	21.5	32
M12N x C4	M12	79	2	77	24	19	13	21.5	54.5
M16N x 65	M16	65.5	2	63.5	33	25	17	24	38.5
M16 x 75	M16	75.5	2	73.5	33	25	17	24	48.5
M16N x 85	M16	85.5	2	83.5	33	25	17	24	58.5
M16N x C111	M16	106	2	104	33	25	17	24	79
M20N x 100	M20	100	3	97	42	28	21	33	63
M22N x 110	M22	110	4	106	45	31	23	37	69
M24N x 120	M24	120	4	116	50	33	25	40	75

Fine ceramic insert types and dimensions.

Hanging Scaffoldings of Prestressed Concrete with Application of Fine Ceramic Insert," issued by the Japan Institute of Construction Engineering in November 1988, it was confirmed that salt and alkali resistance pose no problems for FCIs.

Financial Implications

FCIs are mainly manufactured in Japan and China. The costs of FCIs have been successfully controlled to be equal to or less than the cost of stainless steel inserts of the same size. While the price of stainless steel fluctuates according to the market prices of nickel and chrome, the cost of alumina materials is quite stable.

Conclusion

The experimental results showed that FCI anchors performed well, providing concrete breakout capacity that conservatively satisfies the requirements of the ACI 318-19 equations. Further finite element method analysis will be carried out at the University of Houston to provide a capacity table for shear and tension, as well as equations for edge conditions.

FCIs can contribute to the longevity and durability of U.S. concrete bridges because their corrosion resistance helps prevent potential paths for deterioration.

References

1. Belarbi, A., and M. Abdelmounaim. 2023. *Experimental Study of Japan Life's Fine Ceramics Insert (FCI)*. Houston, TX: University of Houston. https://www.japanlife.co.jp/wp/wp-content/uploads/2023/11/FCI-Report-7-6-2023.pdf.
2. American Concrete Institute (ACI). 2019. *Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)*. Farmington Hills, MI: ACI.

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