Fast, durable compressor foundation repairs available

Cracks are best fixed with tougher anchor bolts, polymer modified concrete, adjustable epoxy chocks

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Cracked reciprocating compressor foundations can be fixed once and for all and rather quickly if the repair job incorporates proven engineered designs and the better, more appropriate, repair materials that are available today.

The successful result will be longer equipment life and reduced costs from unscheduled downtime and wear-part usage. A compressor's crankshaft alignment determines:

- Machine life and downtime
- Wear-part consumption
- Necessity for a regrout or foundation repair.

When foundation repair is needed, it should be viewed as a chance to upgrade the foundation, address the root cause and prevent reoccurrence. A foundation upgrade can more adequately address typical alignment-related foundation problems, such as cracking and deteriorating foundation integrity and stability, than a simple regrouting job.

Foundation upgrade. In a thorough upgrade project, the foundation should be rebuilt and reinforced with reinforcing bars (rebar) to today's standards. The chocks should be upgraded to an adjustable epoxy chocking system. The anchor bolts should be repaired or replaced with new high-strength bolts made per ASTM A-193 specifications.

A compressor foundation must absorb and transmit dynamic loads in the mat and subsoil (Fig. 1). To do this, it must be monolithic and properly reinforced with rebar. Reinforcement is most important in the upper block area where the foundation must have the highest tensile load capacity.[1] The best way to achieve this with today's materials is with rebar-reinforced concrete material.

Foundation cracks, particularly those in the lower block, cannot be corrected by simply chipping out the old grout and pouring new grout. Chances are the underlying problem will reemerge and eventually will have to be corrected. Horizontal and vertical foundation cracks, especially those weeping oils or fluids, must be addressed.

Cracks in the upper foundation can be repaired by chipping out below the crack line for horizontal cracks or until the crack is gone for vertical cracks. A concrete repair material, reinforced with rebar, is used to rebuild the foundation. Finally, a two to four-in.-thick epoxy grout cap is poured on top to form a precision, non-shrinking, chemical-resistant cap. An adjustable epoxy chock is installed at each anchor bolt to provide a precision adjustable support system.

Lower foundation block cracks present an economic and engineering problem. Economics usually do not allow for a complete foundation replacement, but a simple regrout will not correct the problem.

The solution is to rebuild and reinforce the upper 18 to 24 in. of the block with a concrete repair material. During the rebuilding project, cracks in the lower block are bridged with post-tensioning bolts to bring the lower block into a more monolithic state. The highly reinforced upper repair area is post-tensioned to the lower block repair to tie the entire block back together. While not as good as a new block, this is an economic solution that is better engineered and longer-lasting than a simple regrout.

Grout limitations. Standard concrete must cure for 21 to 28 days before epoxy grout can successfully be applied. Because of this expensive downtime, many have tried using epoxy as a concrete repair material. This produces problems inherent to epoxy grout.

Epoxy machinery grout was invented to replace cementitious grouts, typically applied to a thickness of two to four inches. This particular grout cannot be reinforced with rebar as cementitious

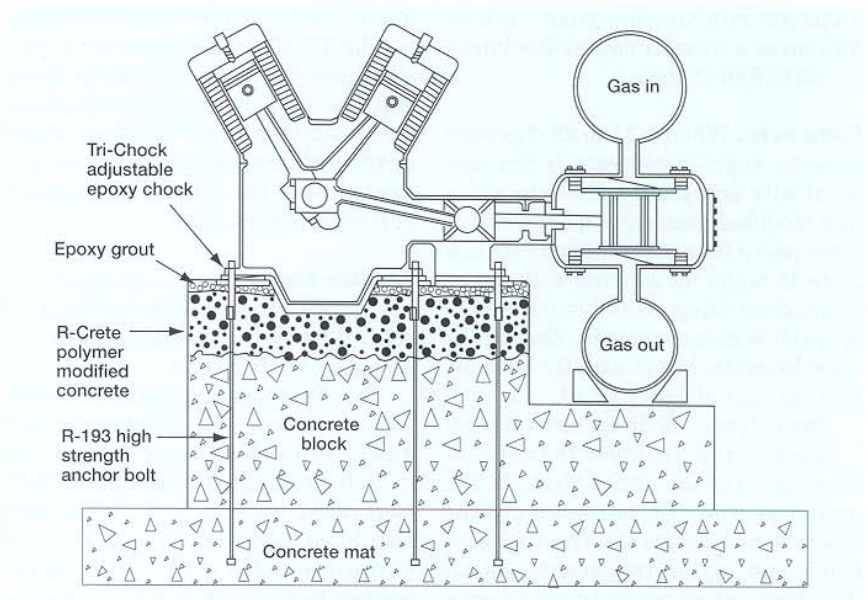

Fig. 1. Upgraded reciprocating compressor foundation.

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materials can. This is because steel and epoxy grout differ in their thermal coefficients of expansion and moduli of elasticity. Epoxies, with their high tensile strength, do not transfer tensile loads to the rebar as cementitious material does. This is because epoxies, unlike concrete, have such a low modulus of elasticity that they stretch rather than transfer tensile loads to the rebar.

Epoxy grouts have a modulus of elasticity about half that of concrete, in other words, epoxy grouts compress about twice as much as concrete when loaded equally. This explains many field alignment problems and catastrophic crankshaft failures where foundations had been repaired with a deep pour of epoxy instead of higher modulus concrete repair material.

The material can creep or cold flow over time, further contributing to alignment problems. The creep problem is exaggerated by both thickness and temperature.

Polymer-modified concrete. Compared to epoxy grout, concrete and polymer-modified concrete have virtually no creep.

This distinction is especially important because most foundations are not chipped to a constant elevation when cracks are removed. If epoxy grout is used instead of cement to rebuild the chipped foundation, wide differences in the epoxy grout depth of pour can cause different amounts of compression and creep. Epoxy's compression and creep problems can be tamed by rebuilding the foundation with concrete or polymer-modified concrete and topping it with an epoxy grout cap that measures a more constant thickness of two to four inches.

Cure rate. When a 21 to 28-day cure time for regular concrete is not economically acceptable, R-Crete polymer modified concrete is a competitive alternative because it is ready within 24 to 48 hours for capping with epoxy grout, depending on ambient temperature. It is more expensive than standard concrete, but it usually is about half the cost of epoxy grout.

The polymer-modified concrete can be used to repair upper foundation block areas or the entire block. It has proven itself over the last seven to eight years to be preferable, from an economic and engineering standpoint, to deep epoxy-grout pours. In one job on a busy transmission mainline, a complete foundation block was replaced with the polymer concrete. The material cured in 24 hours and the entire repair project, from compressor shutdown to re-start, was completed in 32 days.

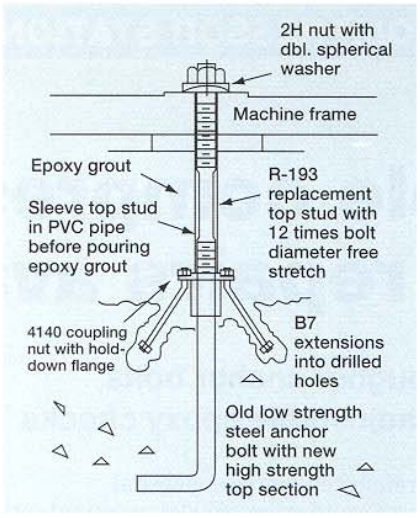

Fig. 2. Anchor bolt repair involves chipping old grout and concrete out to a depth of 18 to 22 inches below compressor base.

Adjustable epoxy chocks. During any foundation repair project, the support system and anchor bolts should be upgraded to current standards. Tri-Chock adjustable epoxy chocks have displayed the ability to improve alignment, measured by wear-part reduction, compared to full-bed grout, steel chocks, steel sole plates and regular epoxy chocks.[2]

Adjustable epoxy chocks have shown they can cut alignment adjustment time to about 20 to 30 minutes per anchor bolt, compared to two or more days with regular epoxy chocks and up to a week if a steel chock must be custom machined.

The Tri-Chock does not use expensive horseshoe shims. This saves money and time. Compressor alignment adjustments and crank web deflection and bearing clearance checks can be performed while the compressor is close to operating temperature.

Anchor bolts. Horizontal and vertical reciprocating compressor loads are controlled by the clamping force produced by anchor bolts.

This force prevents excessive movement and wear on moving parts, such as the crankshaft and compressor cylinder rods. In a thorough foundation repair project, old anchor bolts should be upgraded to high-strength two-piece bolts such as the R-193 anchor bolt series, made from 4140 steel per ASTM A-193.

Many older bolts are A36/307 mild steel. If access or economics preclude complete bolt replacement, the old bolts should be cut off and upgraded to allow for the greater capacity of a new high-strength R-193 top section (Fig. 2). An R-193 bolt repair kit is available, designed with an additional flange and B-7 "allthread" tendons to help upgrade old bolts.

If access allows, the old bolts should be completely cored or chipped out and replaced. Whenever possible, the new anchor bolts should terminate in the mat to provide additional post-tensioning benefit.

New anchor bolt top sections should be wrapped in foam or enclosed in PVC pipe, freeing them to stretch. The top section should be "necked down" per ASTM to provide a frangible section. This is because foundations and many compressor frames would fail before the bolt achieved proper stretch, when the bolt had been tightened at full diameter.

The bolt top section should be shot peened per military specifications for additional surface hardening and to reveal any delamination during the thread rolling process.

Washer. A 4140 double-spherical washer, hardened per F 436, will prevent point loading to the 2H nut caused by either out-of-level "nut bosses," or frame thermal growth. This prevents stress planes produced by point loading from breaking bolts below the nut.

The coupling nut used to join the top and bottom bolt sections and the double-spherical washer should be made from 4140. Softer steel would allow the bolt to relax more and lose its torque. The washer must be hardened to prevent both crush and torque loss.

The coupling nut should be heat treated and gauged to see that it still provides a class 2B fit. The gauging is particularly necessary if the heat treating is done after drilling and tapping. Gauging ensures that the tread engagement still meets a class 2B fit. All anchor bolts, couplings and 2H nuts should be eight threads per inch (TPI), providing more thread engagement and strength than coarse, 4½ or 6 TPI.

LITERATURE CITED

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[2] Rowan, Robt. L., P.E., Larry Phelps and Mark Gerkin, "Control of Crankshaft Distortion with an Adjustable Epoxy Chocking System," Reciprocating Machinery Conference sponsored by Southern Gas Association.