

## Case Studies of Central Office Cable Tray Support Failures

Dan McMenamin  
Specialist - Energy & Environment

Bell Atlantic Corporation  
1717 Arch Street Suite 1700  
Philadelphia, Pennsylvania 19103 USA  
215-466-2125

### Abstract

An otherwise uninteresting telephone central office becomes an exciting post during the collapse of overhead cable trays bearing thousands of pounds of cabling. Although most systems engineers don't get too worked up over a spiffy new concrete anchor design, such lowly devices are an extremely important consideration when designing for network reliability.

Most central office cabling is supported on overhead cable racks or trays. Before the advent of Stored Program Control Switching systems (SPCS), most central office equipment frames were 11.5 feet (295 CM) tall, and provided most of the structural support for overhead framing and cable tray systems.

SPCS frames and modern transport equipment frames tend to be approximately 7 feet (178 CM) tall. Express cable trays to the power plant and Main Distributing Frame (MDF) areas are usually supported by an auxiliary framing grid suspended from the ceiling slab. From a structural and earthquake protection viewpoint, both the equipment frames and the overhead structures are now separate and independent systems. This is a superior design plan, especially where building vibration or seismic activity is a consideration.

Since metallic cabling, especially copper power cables, are quite heavy, all support elements must be capable of handling massive loads safely and reliably. Virtually all of the weight is borne by cast-in-place structures such as ceiling inserts, and embedded channel struts, or by anchors which are drilled and set by a variety of fastening systems. During office growth and modernization, or switching system replacements, engineers often find that the existing anchor grid-pattern is inadequate for the new switching equipment's cable trays.

While it seems a simple matter to provide additional anchors, two recent cable tray collapse failures in eastern Pennsylvania underscore the fact that some anchor designs are more prone to failure than others. The collapse of cable trays is a disconcerting experience well worth avoiding. This paper will share case studies of the two failures, and their root-cause investigations. Additionally, the paper will share the results of dynamic pull-out tests, performed both in the laboratory and the field, on several traditional and newer style anchor designs, exploring their merits and drawbacks.

### Wayne Pennsylvania

Two cable racks fell in the Central Office at Wayne, PA, a Philadelphia suburb. The racks are directly above a 30,000 line digital switching machine. Fortunately, some of the ceiling anchors were cast-in-place types which held when the installed anchors pulled out. Therefore, the cable racks and low-type auxiliary framing fell only a short distance before striking a masonry wall where the mass sat cantilevered. The remaining threaded rods bent spring-like and the assembly was reminiscent of a swimming pool diving board. There was no loss of telephone services.

The failed rack supported approximately an eight-inch (20 Centimeter) pile-up of line and trunk switchboard cables from the digital switching machine to the office Main Distributing Frame. The rack is approximately twenty inches (51 Centimeters) wide and eighteen feet (6 Meters) long. At the heaviest loaded end, the rack, cabling and framing weigh an estimated 2,400 pounds (1090 Kg). The estimated load per anchor is approximately 300 pounds (136 Kg), well below the 1,200 pound (545 Kg) safe working load of the anchors. Safe working load is considered to be 25% of an anchor's ultimate load.

Another rack carrying approximately 20 runs of 750 KC-Mil power cable suffered similar failure with several anchors experiencing a partial pull out.

The anchors which pulled out are double action expansion shield types (see sketches and photo of threaded rod and anchor). The anchors were installed by a buildings construction contractor approximately three years ago. Investigation of the incident revealed that the concrete was quite strong; its' compressive strength measured more than 7,000 PSI with a rebound hammer. The anchor installation, however, was flawed in several ways.

The anchor requires a hole one-inch (2.54 CM) in diameter by three-inches (7.62 CM) deep. The first hole drilled by the contractor struck a reinforcing rod (called REBAR in the trades) embedded approximately 5/8-inch (1.6 CM) into the concrete. The proper procedure, at this point, is to move over approximately two inches (5 CM) and drill again. The mechanic drilled the second hole approximately 3/4-inch (1.9 CM). The result was a deformed hole as shown in the sketch marked "Failure Sequence."

Wayne, PA

(4) Double-Action Anchors Pulled-Out

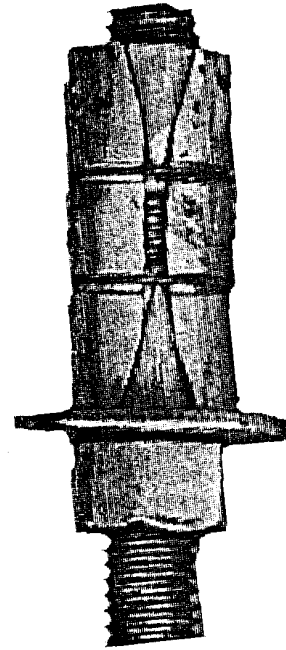
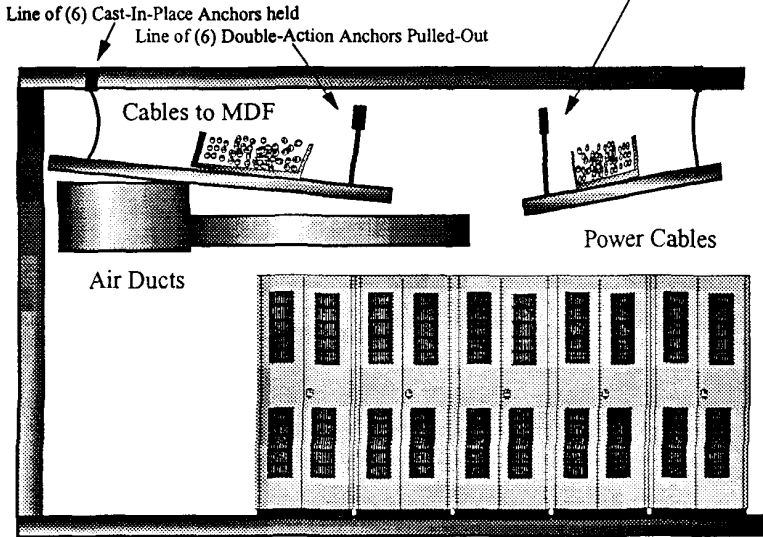
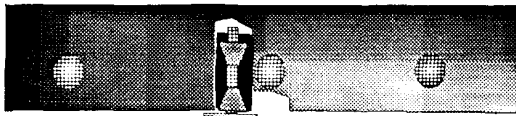
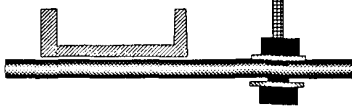


Photo - pulled-out anchor from Wayne (tape removed)



Failure Sequence



1. Contractor drilled and struck REBAR.
2. Contractor drilled second hole too close to first.
3. Contractor drilled hole slightly wide.
4. Contractor wrapped duct tape around anchor.
5. Installer added threaded rods & framing.
6. Weight (cable) placed on rack.
7. Anchor carrying approximately 300 LB (136 Kg).
8. Anchor pulled out.

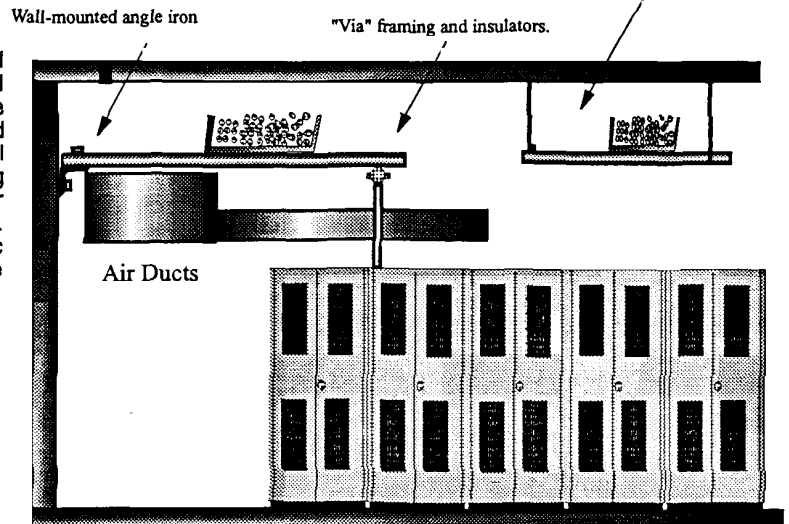
Conclusion: Expansion shield had insufficient friction with concrete because the hole was deformed and the duct tape acted like a lubricant.

Repair/restoral

Temporary repairs employed stanchions and jacks to support the mass of framing and cabling. Because of the hole deformity, anchors could not be set in the existing holes. Since digital switching systems are sensitive to dust, prudence dictated the repair be accomplished without drilling directly above the switch. A length of angle iron was fastened to the wall to support one end of the framing (see repair sketch). The other end was supported using the switching equipment frames for support, with standoff insulators used to maintain the integrity of the isolated ground plane.

Wayne Repairs

Power rack resupported using nearby framing.

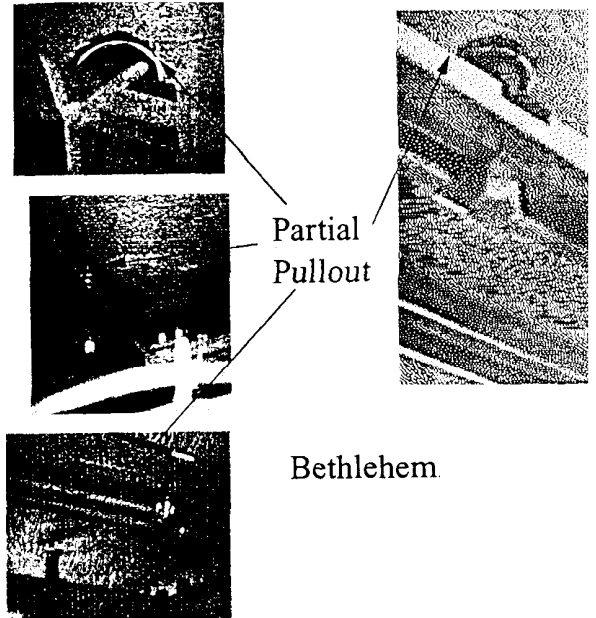
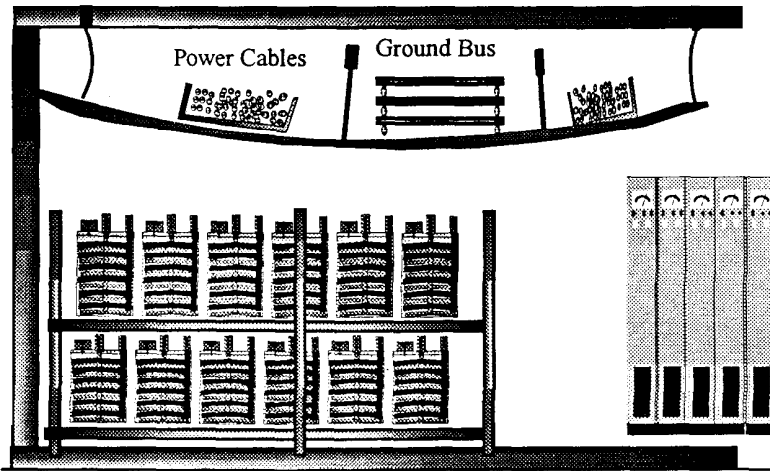


At this point, the mechanic inserted the anchor and attempted to set it using a 5/8-13 hex-headed bolt and washer. The anchor wouldn't set, instead, it spun in the hole. The mechanic removed the anchor and wrapped it with duct tape in the mistaken belief that it would fill the gap between the anchor and the hole, thus allowing the anchor to set. Obviously, expanding the anchor slightly with the bolt would have been a better choice. Regardless, once the bolt was tight, the mechanic believed it "set" and removed the bolt. Some twenty-four anchors were improperly installed this way.

A telephone equipment installer screwed-in threaded rods and tightened them with flat-washers and 5/8-13 nuts. Because of the hole deformity and the duct tape drastically reduced the shield-to-concrete friction needed to secure the anchor, the framework and cable rack assembly pulled the anchors out of the ceiling beginning at the heaviest end, and progressing towards the lighter end.

Bethlehem, PA

(~14) Single-Action Anchors Pulled-Out



**Bethlehem, PA.**

Bethlehem Central Office provides telephone services to approximately 25,000 lines in this small industrial city approximately fifty-five miles North of Philadelphia. Telephone switching is provided by an analog switching machine and a digital switching system. By October, 1994 when this INTELEC conference takes place, the office will be entirely digital.

A partial cable rack collapse occurred in a basement power room. The problem was discovered after a small earthquake measuring approximately 4.3 on the Richter scale shook Reading, a town some 40 miles to the West. Close examination of photographs taken more than a year ago, however, show some anchors beginning to slip. Accordingly, the earthquake is not considered a causal event. As may be seen in the sketches and photos, a partial pull-out of the ceiling anchors occurred, allowing the framing to bow in the center.

The combined weight of the cables, racks and framing in the area is estimated at 1,600 pounds (727 Kg), with an average of 270 pounds (122 Kg) supported by each anchor. Remarkably, some of the pulled-out anchors were carrying less than fifty pounds (23 Kg). The anchors were single-action expansion shields 2-1/2 inches long, rated at 1,500 pounds (680 Kg) safe-working load specified by the manufacturer.

Investigation revealed that the concrete averaged more than 6,000 PSI, compressive strength as measured with a rebound hammer. The holes were clean and not excessively "powdery." The anchors felt snug in the holes, even when they were "unset" with a hammer blow to the loosened threaded rods, indicating that the holes were correctly sized. Some of the nuts seemed a bit loose in the field, and our initial reaction was that this contributed to the failure. Tests performed in the laboratory, as noted herein, show that even light loads cause sufficient "creep" in the expansion shield for tight nuts and washers to actually lose contact with the ceiling.

As such, this is an unexplained failure, thought (probably) to be anchors poorly set at installation time, some thirty years ago. Because the power equipment is less dust sensitive, new holes were drilled and drop-in type anchors added.

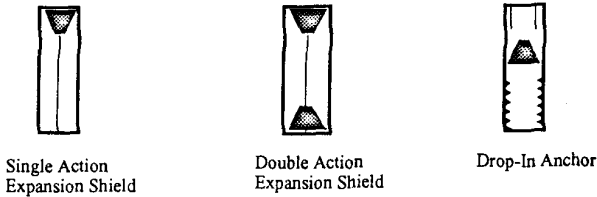
**Orchard Central Office (Field Tests)**

As a result of the Wayne and Bethlehem failures, the Maintenance Engineering and Buildings Engineering organizations decided to test a new installation at Orchard Central Office in Northeast Philadelphia. The office has a 60,000 line digital switching machine, which was under construction in April, 1994 when the test took place. The framing is supported by a grid of approximately seventy 1 X 3 inch double action expansion shields. The nuts and washers were checked and found tight.

With assistance from Bellcore Mechanical Protection engineers, a test apparatus placed a 2,400 pound (1090 Kg) load on several threaded rods. This represents approximately 200% of the load the rods and anchors are expected to carry in the field, or less than 50% of the manufacturer's specified 5,500 pound ultimate strength. Application of the 2,400 pound load to the six anchors tested resulted in "creep" (displacement) of the anchor's interior (the upper expansion cone) causing the threaded rod to drop slightly, permitting the nut and washer to lose contact with the ceiling in half of the cases as follows:

Displacement (Inches)	Test Load Results	
	Displacement (Inches)	Displacement (Millimeters)
1	0.00	0.000
2	0.10	0.025
3	0.00	0.000
4	0.20	0.050
5	0.30	0.076
6	0.00	0.000

### Anchor Types Tested



#### Laboratory Testing

At the request of Bell Atlantic, joint tests were conducted at the Bellcore research facility in Chester, New Jersey. Three types of anchor were tested: single and double action zinc-alloy expansion shields, Steel-alloy and Drop-In type anchors. Several units of each type were tested. One of the double action types tested was removed from the Wayne Central Office.

The purpose of the test was to determine whether zinc-alloy expansion shields are adequate for continued use in new work, or if another approach is warranted.

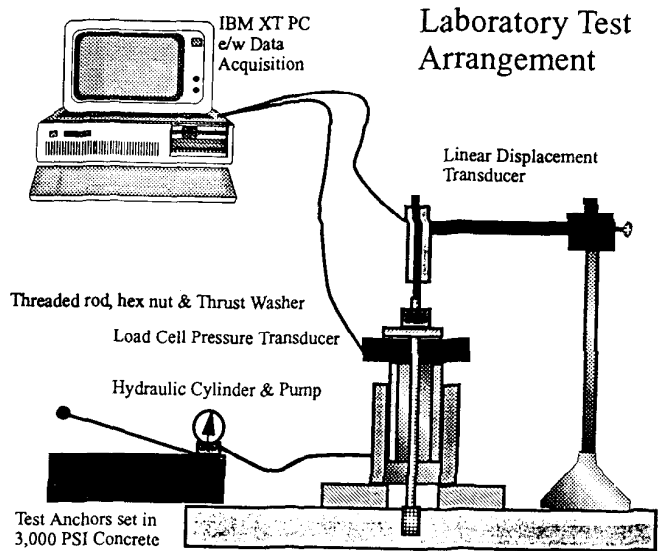
A sketch of the test apparatus is shown herein. Essentially, a hydraulic cylinder was arranged to pull against a threaded rod set into the anchor under test. A load cell transducer measured the "weight" produced by the pull, while a linear displacement transducer measured the "creep" or displacement, either of the expansion cone within the anchor, or of the anchor itself. The concrete slab was four inches (10 CM) thick had a compression strength in excess of 3,000 PSI.

The single action expansion shields experienced 0.09 inches of creep at 2,500 pounds of load. At 7,150 the creep was 0.58 inches. As the test proceeded, the expansion cone traveled to 0.83 inches and caused stress fractures in the concrete slab. Cones of concrete some eight inches in diameter and 1.75 inches deep fractured out of the slab with the total failure of the anchors.

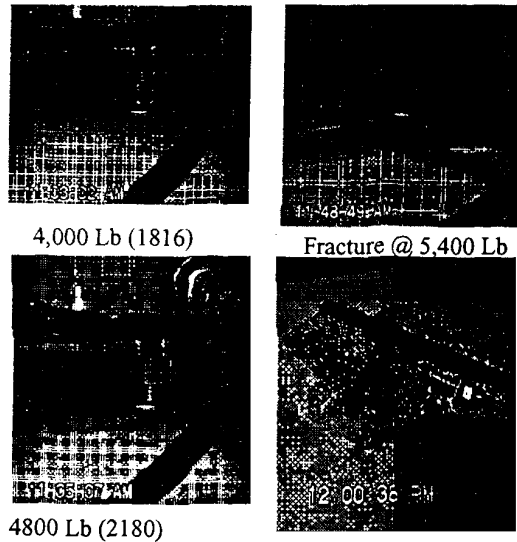
The double action type expansion shields fared a little better. Creep at 2,500 pounds was 0.14 inch. Creep at 10,550 pounds was 0.52 inch, through 0.77 inch at the end of the test. There was no fracture of the concrete during any of the double action tests.

Addressing the "Wayne" problem, a set of holes were drilled to match the hole-deformation found at Wayne. A double action was installed in one set, and an actual anchor from Wayne was set into the other one using a duct tape wrap, as had been done at Wayne. In both cases, the anchors pulled out, approximately 1.5 inches, the "Wayne" anchor began to slip with as little as 400 pounds (182 Kg) load.

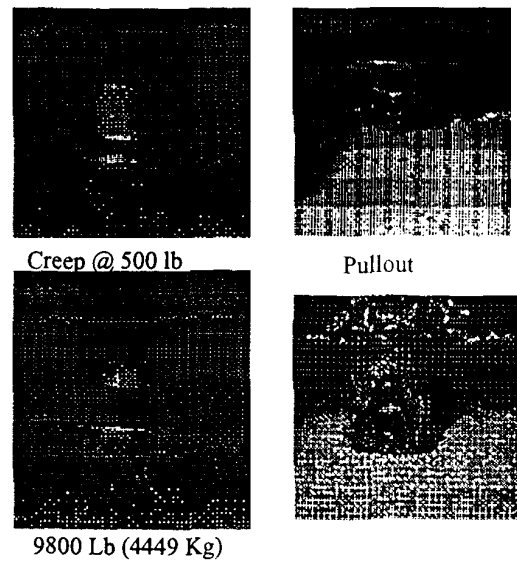
Drop-In anchors were tested with very encouraging results. They experienced 0.04 inches of creep at 2,500 pounds and only 0.05 inches at 11,000 pounds. Since Drop-In anchors rely on a drift pin type punch to set them, some were installed deliberately without bottoming out the punch to simulate a somewhat improper installation. The test results were identical to the properly installed units.



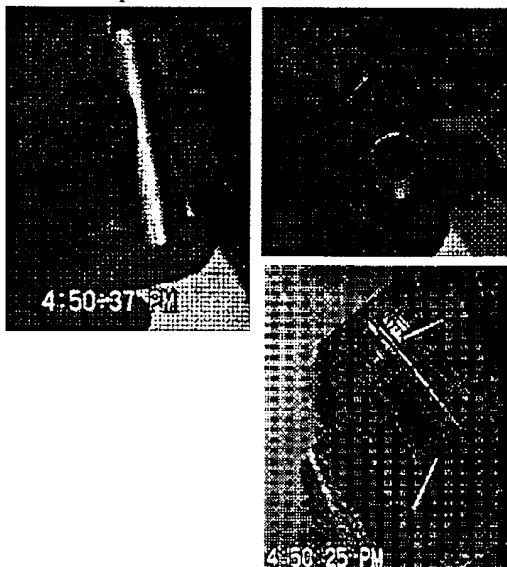
#### Lab Test Single Action Zinc Alloy






#### Lab Test Double Action Zinc Alloy



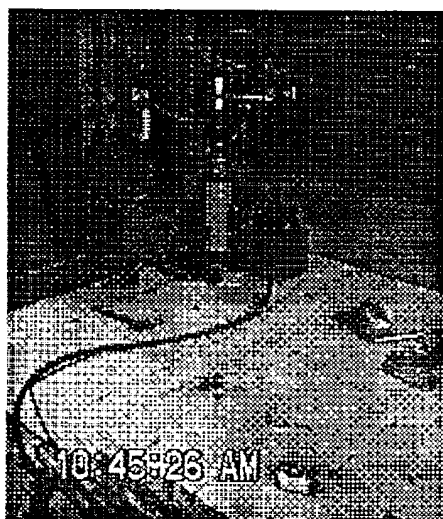
Drop-In Anchor



Author's Conclusions

		
Single Action Expansion Shield	Double Action Expansion Shield	Drop-In Anchor
Failed in Field	Failed in Field	No Field Failures
Performed Poorly in Laboratory	Performed Marginally in Laboratory	Superior Performance in Laboratory
Poor	Marginal	Best-In-Class

Test Slab



Laboratory Conclusions

This engineer (the author) finds that, clearly, the Drop-In type anchor performed better than the expansion shields in the laboratory. The anchor experienced less creep - whether installed properly or not, supported more weight, and caused no damage to the concrete.

The tests also proved conclusively that both the hole deformation and the misapplication of duct tape were the root causes of the problem at Wayne.

Overall Conclusions

Although zinc alloy expansion shields have enjoyed wide use in central offices for decades, they did not perform well at Wayne, Bethlehem, or in the lab. The anchors tested failed to meet the manufacturer's specified ratings. Since creep caused once-tight nuts to loosen in the field, we might have to tighten them periodically - perhaps after cables are added to racks. This is an added expense no one needs.

There appear to be better products available which cost about the same or less overall. Drop-In type anchors are made by several reputable vendors. They are easier to install and require no maintenance. They use a slightly smaller diameter hole for standard 5/8-13 rods (18 MM vs 1-inch) so there is slightly less chance of striking REBAR during the drilling process. Also, if 2-inch bar or channel-type framing is sagging, an 18 MM drill bit will fit in the narrow space between the framing members allowing additional anchors for reinforcement without temporary supports or framework disassembly. In fact, this method was used to repair Bethlehem.

All things considered, this engineer is sold on Drop-In anchors.

Acknowledgements

The author wishes to acknowledge the valued assistance of Richard Gemra, Richard Kluge and John Murphy - Members of Technical Staff - Bell Communications Research (Bellcore) during the investigation of these incidents and the testing of the anchors.