

What are “Free Form” angle sets?

Simply put, “Free Form” angle sets are set of angles that do not follow a LISCAD operation code 3 in the data collection file, and are therefore not restricted by the processing of data according to that code. Using the free form approach, LISCAD will accept and adjust observations in just about any sequence the total station operator chooses to collect the data, hence the term “free form”. However, it is currently believed that, in practice, free form should be limited to specific situations and a defined sequence should still be followed.

The concept of “Free Form” angle sets was born out of a need to get on and off certain points quickly. ODOT has consistently used the “Code-3” method of collecting multiple observations to the same point. However, this restricts the process to a rigid sequence, requiring that each foresight be tied twice, once in direct mode (face 1) and once in reverse mode (face 2). This rigid sequence forced the field crew to practice one of two procedures during data collection.

1. Visit each foresight two or more times. This could present significant disadvantages, as described in the table above.
2. Observe the backsight once for each observation on a foresight. This increased the number of observations required and the time required for the data collection.

In reviewing the initial training on LISCAD provided by Leica, it was discovered that none of their sample least squares adjustment files contained code-3 angle sets. Further experimentation revealed that LISCAD would adjust individual observations in much the same way that it does for angle sets.

From that, ODOT Geometronics developed a procedure for what has been labeled as “Free Form” angle sets. Along with the procedure, a guideline was also developed to define when use of free form is appropriate and when it is not.

The motivation for implementing free form set within ODOT is based on the following objectives. Other applications may be developed in the future.

- Eliminate the need to carry numerous tripods during monument ties.
- Eliminate the need to visit each monument multiple times.
- Accommodate the need of moving operations to get on and off a point quickly.
- Eliminate the need to re-observe the backsight each time the foresight targets are moved.
- Eliminate the need to leave tripods in awkward or hazardous locations while sweeping through other targets.
- Facilitate flexibility in observation sequence, as when two rods are in use, the operator can observe first whichever is ready first.

Comparison of traditional "Code-3" angle sets versus "Free Form".

Code-3 Angle Sets	"Free Form" Angle Sets
Advantages of using "Free Form"	
Setup time for multiple tripods	Minimal setup time for plumbing pole or bipod
Significant Equipment requirements - Tripods on each foresight	Minimal equipment needs - no tripods on foresights
Difficult to leave tripods in hazardous locations.	No tripods to leave in hazardous locations.
Moving operations need to visit a point multiple times, once for each arc.	Moving operations need only visit a point once, regardless of number of arcs.
Requires visiting hazardous locations twice for direct and reverse observations.	Hazardous locations can be tied direct and reverse or even more with one visit.
Requires observing backsight multiple times for large number of foresights.	Backsight requirements are unaffected by the number of foresights.
Single sets (Fly points) ignored in least squares.	Purely redundant observations will cause point to be included in least squares.
Any number of observations within a given angle set is given equal weight in the adjustment.	Additional observations add weight to adjustment.
Observation sequence can be modified at any time.	Observation sequence must be followed rigidly once the code three is issued,
Advantages of using "Code-3"	
Produces a set summary in LISCAD for each defined set of angles.	Does not produce a set summary in LISCAD because there are no sets defined.
Produces fewer observation entries (one for each defined angle set) in the least squares editor and report.	Produces additional observation entries (one for each observation) in the least squares editor and report.
Point numbers can be entered only once for each set.	Point numbers must be correct for each observation.
Target heights can be entered only once for each defined angle set	Target heights must be correct for each observation.
Works well with "Sets of Angles" program.	Questionable benefit from "Sets of Angles" program.

The procedure for collecting "Free Form" angle sets.

With those objectives in mind, the crew collecting data using free form would follow this procedure.

1. Setup the instrument and backsight as when using the code-3 method.
(A tripod is optional on the backsight as it need not be observed multiple times like in the code-3 method.)
2. Issue all normal codes except the code three.
3. Set the point number increment to zero in the total station.
4. Follow steps 5-10 for the initial backsight.
5. Set the correct point identifier in the total station for the point to be observed.
6. Using a code 2, set the correct target height for the target to be observed.
(This step can be omitted if the last target height entered in codes 1 or 2 is still valid.) Note that the target height must be correct for **ALL** observations.
7. Observe the target in direct mode. (Face 1)
8. Verify that the point identifier in the total station is still set on the correct number. Note that step 3 above should insure this, and note that the observation will not process correctly unless **ALL** point numbers are correct.
9. Observe the target in reverse mode (Face 2)
10. If desired, additional sets can be recorded to this target by repeating step 7-9
11. Repeat steps 5-10 for each foresight in the set.
12. Repeat steps 5-10 for any additional backsights in the set.
13. Repeat steps 5-10 for any the original backsight in the set. This should always be the last step in completing the set.
14. Set the point number increment back to one in the total station when finished with free form sets.

The procedure for processing "Free Form" angle sets.

Processing of free form data is similar to other least squares adjustment data. Differences are shown in ***bold italics***.

1. Download, backup, label, and edit the data.
2. Create a field file.
3. Extract the field file into the Control Editor. ***There will be no set summary created.***
4. Extract and adjust the field file and save the resulting adjustment report.
5. Analyze the adjustment report for suspect data.
 - ***Standard ODOT network acceptance standards are not rigidly applicable.*** ODOT LISCAD User Tip #8 on monument ties mentions meeting network standards for residual values, and this would be ideal. However, the double ties on monuments, strategic points, and photo control marks are performed to detect blunders, not necessarily to refine position. Distance residuals, and particularly on short observation lines, angular residuals may be out of tolerance without having a detrimental effect on the position of the point. Significant blunders should be obvious.
 - ***A bad backsight distance will result in one distance residual about equal to the magnitude of the error.***
 - ***A bad backsight angle will result in one angle residual somewhat less than the magnitude of the error and the backsight angle residuals slightly high.***
 - ***A bad foresight distance or angle will result in large residuals to that point. Residuals will be equal in magnitude and have opposite signs if no other data is available. Each residual will be equal to about one-half of the magnitude of the error. This will vary if additional observations are taken. As more observations that are correct are included in the adjustment, the observation with the error will become more apparent.***
6. Update the spreadsheet and the database.

Proper use of "Free Form" angle sets.

The Geometronics Unit evaluated the use of free form angle sets for various tasks the department currently carries out using code-3 angle sets. We identified some applications that are quite advantageous and others that we determined were problematic.

For the most part, most points that we would tie with a single angle set would be appropriate for free form. This would include property monument ties and ties to photo-control marks. One notable exception is our standard strategic point.

Using the free form method requires the tie be adjusted through least squares. The direct reduction of a file containing free form angle sets will generate warning messages and will only use the first angle and distance in each set.

By contrast, the code-3 method for strategic points allows it to be reduced along with the rest of the topographic data. The code-3 method should continue to be the standard for strategic points. However, it should be noted that this procedure would not identify any blunders unless a set summary is run.

The other area where free form should not be used is a control network. There are a couple of reasons for this.

While the Geometronics Unit is continuing to evaluate the options, it is clear that the statistical data changes substantially when network observations are processed as individual observations rather than sets. What is perhaps more significant is that mixing of free form and code-3 data will apply inappropriate weighting to the adjustment.

Another reason for avoiding free form set in control networks is the magnitude of data generated by this process. A standard set of code-3 angles will create one line each in the angular residual and distance residual sections of the adjustment report. By contrast, the free from method would create eight time that amount of residual data, each of which should be evaluated before excepting the final network adjustment. ODOT crews should continue to exclusively use the code-3 angle set for network observations.

The following applications are appropriate for use of free form sets.

- Property monument ties in most situations.
- Photo-control targets

The following applications are **not** appropriate for use of free form sets.

- Network observations
- Strategic points