TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE UTAH NATURAL RESOURCES CONSERVATION SERVICE

March 2015

ENG -210 - TECHNICAL NOTE UT210-15-01
190-VI

SUBJECT: ENG – Structural Design of Flexible Conduits – Plastic Pipe

Purpose. To transmit a spreadsheet that performs the calculations from NEH Part 636, Chapter 52, *Structural Design of Flexible Conduits*, and instructions for its use

Effective Date. Upon receipt.

Contents of Technical Note.

SUMMARY

In June of 2005, Structural Design of Flexible Conduits, was released in Part 636, Chapter 52, of the National Engineering Handbook. Flexible conduits are defined as pipes that will deflect at least 2% without structural distress. Flexible pipe materials consist of the following: smooth-wall steel pipe; corrugate spiral rib or composite ribbed metal pipe; ductile iron pipe; and solid-wall, corrugated-wall or profile-wall thermoplastic pipe (PVC, ABS or PE).

The equations from Chapter 52 have been loaded into a spread sheet for calculation. This technical note introduces the basics of that spread sheet. Although Chapter 52 also gives information for plastic and metal pipe (steel & aluminum), this spread sheet has been written for calculations on ***only*** thermoplastic pipe, commonly called plastic pipe.

Link to Spreadsheet:
http://efotg.sc.egov.usda.gov/references/public/UT/chapter_52_final.xls

INTRODUCTON

There are 8 sections to compute different aspects of internal and external pipe characteristics of flexible conduit. The spread sheet has been separated to provide a worksheet for each of the 8 sections. In order to make calculations easier and less repetitive, one input sheet is used for all data entry for evaluation of each pipe. All data loaded into the input sheet is then cross filled to the appropriate worksheet where the specific inputs and equations are located.

The Chapter 52 Sections (followed by worksheet name in parenthesis) include:

- **636.5201 Internal pressure design (PVC and HDPE)**

  The pipe pressure rating in a flexible plastic pipe is stamped on the pipe, along with plastic pipe material and diameter. Data from the manufacture on pressure, outside diameter, wall thickness, and standard diameter ratio (SDR) is used on the input sheet and throughout the other worksheets. This data is loaded in the pipe dim worksheet.

- **636.5202 Water hammer/surge pressure (surge)**

  Plastic pipe *design* pressure is limited to 72% of the pipe pressure rating to allow for water hammer. This spread sheet calculates surge pressure for the planned scenario and determines if a pressure relief valve is necessary, and if needed, it recommends what size to use. The operating pressure and pipe pressure rating can be changed to minimize the size and/or the need for pressure relief valves.

- **636.5203 Loads on pipe (loads)**

  The external loading on the pipeline from the soil, wheel loadings, internal vacuum, and an external water table are calculated to determine if the wall thickness is adequate. The hydrostatic pressure from water outside the pipe acts the same as an external load. The soil type, depth of cover and equipment type are used to determine if the pipe is heavy enough.

  An internal vacuum can occur as water vacates a section if there is not adequate venting in the line. This vacuum acts the same as an external loading. Adequate venting will reduce the potential for a vacuum. The spread sheet allows for a vacuum to be added into the evaluation.

- **636.5204 Buried pipe design (buried pipe)**

  The typical modes of failure of buried flexible pipe include:
  - Wall crushing
  - Deflection
  - Wall buckling
  - Strain

  These are all calculated based on user selected backfill material, depth of cover, and degree of compaction.

- **636.5205 Expansion and contraction (exp and contraction)**

  All pipe materials expand and contract with temperature change. The coefficients of thermal expansion for selected plastic pipe have been entered to calculate the changes in length for the pipe proposed. The temperature change would generally be greatest during installation and is more noticeable in fused pipe where long sections of pipe are common. PVC gasketed pipe usually expands and contracts in each individual 20 ft. section of pipe so it does not normally create a problem.

- **636.5206 Aboveground pipe design (aboveground)**

  Plastic pipe is not normally recommended for above ground suspension. However there are locations where short spans of plastic pipe can be used in suspension. The sub sections on aboveground pipe are:
  - Bending stress
  - Deflection
  - Hoop stress
  - Total stress at the saddle support
  - Buckling

  The subsections are used to determine the maximum unsupported length the pipe can tolerate. The amount of deflection is also calculated for these short above ground spans.

- **636.5207 Thrust block design (thrust)**

  To define the thrust block dimensions the thrust block section uses the pipeline operating pressure and pipe diameter from the input sheet along with the soil allowable bearing with the cover over the thrust block. The 'cover over thrust block' value is different than the 'maximum cover over pipe' in the bearing capacity value. The cover over thrust block depth would be the *minimum* at the thrust block. The 'maximum cover over pipe' is the *maximum* height of cover depth over the top of the pipe.

- **636.5208 Longitudinal bending (bending)**

  The longitudinal bending is the maximum angle the pipe can be curved without exceeding allowable stress. This is not the amount of change of direction allowed in a joint but in the pipe itself. To make it easier to measure in the field, in the worksheet the angle is converted to a deflection distance for a 20' section of pipe. For example rather than a 5^0 deflection angle it will be stated as 1.5 ft of deflection for a 20' pipe length.

OTHER WORKSHEETS

- **Input**

  The input worksheet has yellow input cells for loading design data. Comments marked by red triangles in the cells, were inserted to explain input information in certain cells. Pull down menus are provided where possible.

  The blue cells are calculations based on the input data. All other cells are locked. The worksheet can be unlocked by using a carriage return. *Use caution in the unlocked mode since the equations can be accidentally erased.*

  The eraser is a push button to clear the values on the input sheet. Please note, after erasing the input sheet, an error comment will appear on the other worksheets, until the new data is entered.

- **Print**
  This worksheet is a written format of your input data. It contains a summary of the input and calculations of your design for the file and design packet.

- **Friction Loss (friction)**
  The Hazen Williams Friction Loss Equation has been entered in the print worksheet to calculate the total friction for the pipe and conditions entered. This is for the pipeline only; bends, outlets, entrance, and minor losses have ***not*** been included. Use this friction loss for planning purposes to evaluate different site conditions, pipe sizes, and flow rates.

- **Pipe dim**
  This worksheet is a listing of pipe outside diameters, wall thicknesses, and inside diameters for the various classes of pipe. The appropriate information will populate the worksheets and the input sheet after using the pull down menu from the nominal pipe dia. - Cell B6.

- **Read Me**
  The read me worksheet provides explanations for the spread sheet.

- **Data**
  The data worksheet has the named cells used for the dropdown menus.

INPUT WORKSHEET DESCRIPTIONS

After opening the spread sheet and reviewing the read me information, go to the INPUT tab worksheet, see Figure 1. Use the eraser to clean out the old data from the input cells.

- **System Parameters Section (cells B3-B16)**
  Enter the landowner name, location, the designer and date. At the Nominal Pipe Dia. cell B6, use the pull down list to select the pipe size, pressure rating and type. The outside diameter (OD), pipe material, pipe type and pressure rating will automatically load in the cells and in the other worksheets where needed.

  The pipe type is generally IPS, however PIP is also available and you should check with your local pipe supplier to be sure. If you choose Schedule 40 or 80 class of pipe the pressure rating in psi for the size selected will fill into the B10 cell.

  The design flow rate can be entered as either cfs or gpm. Use the C11 pull down to enter your choice of units. The B15 cell shows the flow rate for the unit not chosen, gpm or cfs. So if the flow rate is selected in C11 as cfs, B15 will show the flow rate in gpm.

  The final two inputs in the system parameters are entering cell B12, the expected pressure, in psi, for the system and cell B13, entering the length of the pipe in ft.

The SDR, (standard diameter ratio), flow rate and design velocity are shown in cells B14, B15, and B16, respectively. These are based on the data entered above and are provided to check and adjust the input system values. These can be adjusted by changing the pipe size, material type, and/or the flow rate.

- **Soil and Trench Section (cells B18-B21)**
  The soil and trench data requires 4 inputs. The first one, cell B18, is a drop down menu of the soil types. Estimates of the soil weight are shown in cell B19 after a soil is chosen. You can also enter a different weight in the B19 cell that more accurately fits your site.

  Other sources for obtaining soil weights can be found in the physical properties of the soil survey, which give the in-place density in g/cc. This can be converted to pounds/cubic foot by multiplying 62.5 times the g/cc value. Generally most soils weigh between 80-150 pounds/cubic ft.

  The next two input cells are for the cover over the thrust block, cell B20, and for the maximum cover over the pipe in feet, B21. These two inputs can be different since there could be sections where the pipe cover would be greater than at a thrust block. The thrust block cover amount is in a pull down menu that ties back to the allowable soil bearing pressures.

- **External Effects on the Pipe Section (cells B23-B31)**
  The remaining entries will be used to calculate the loads on the pipe. The first cell, B23, is for an internal vacuum. A vacuum can develop in a line where there is inadequate venting which could cause the water column to separate, such as at a high point when the line drains. Two other possible ways a vacuum develops are when the pump shuts off or when a valve is closed, the line drains and air can't get back in the line.

  If not corrected, a vacuum can collapse the pipe. Most classes of flexible conduit can withstand 5 psi of vacuum, which is generally the minimum a line should be designed to tolerate. At 14.7 psi, a total vacuum will occur.

  The next cell, B24, is the depth to a water table above the top of the pipe. Water above the center line of the pipe can add to the external bearing on the pipe.

  Cells B25, B26 and B27 have pull down menus to select the input type. The material used for bedding under the pipe is entered into cell B25. In the next cell, B26, choose the item that best describes the expected compaction of the backfill planned. In the B27 cell, enter the type of backfill material planned for the cover over this pipe.

The load class, cell B28, is used to enter the type of equipment that could cross over the pipe. Farm equipment would normally be used in agriculture areas. H15 and H20 are the standard truck loadings used in the transportation industry.

The B29 cell is the amount of temperature change anticipated for the pipe. Usually after the pipe is installed in the ground, there are only minor temperature changes in the surrounding soils that affect the pipe. This cell is primarily used for above ground systems where the temperature changes can be significant. Allowing the pipe to adjust to the trench temperature over a period of a few hours should minimize the amount of expansion and contraction in a buried pipe.

The last 2 cells, B30 and B31, are used to calculate the amount of stress and deflection in a suspended pipe. This would be for above ground installations. However, there are sites where the pipe is suspended at the inlet and outlet that must be evaluated. Generally plastic pipe is *not* recommended for use as a suspended pipe unless it is a short reach. These cells will evaluate the effects. The saddle contact angle is the degree of contact the saddle has with the pipe at the supports.

PRINT WORKSHEET

The PRINT worksheet is a summary of the input data and computations from the calculations in written format. Data can be entered on the input sheet to accommodate actual conditions at different points along the pipeline. Separate worksheets can be viewed or printed as necessary to support your design.

Example -- Using the input worksheet, Structural Design of Flexible Conduits

Given:

A designer working on an irrigation pipeline in central Washington would like to install a pipeline of 10” diameter, 125 psi PVC pipe. In this area **I**ron **P**ipe **S**ize, IPS, is normally used. The field to be irrigated is 125 acres with 2 cfs of flow. The system has a maximum pressure of 70 psi at the pump (the beginning). The pipeline goes downhill along the 1200 ft length, but has a slight rise through the midpoint.

According to the soil survey report the site soils are fine textured, 60” deep, and weigh 1.4 g/cc. The pipe will be covered with a minimum of 30” of fine sandy loam along the majority of the length except where it goes though the slight rise. The pipe will be maintained on grade and the fill will be a maximum of 6 ft. deep at the rise.

There is a possibility that a vacuum could occur when the line drains. There is no water table in the area. The bedding and backfill material are fine textured. The soil over the pipe will be slightly compacted using farm equipment, so the loading over the pipe will be with farm equipment. The temperature change in the line will be greatest during construction. However the pipe will be laid in the trench overnight before backfilling which will allow the pipe to assume soil temperature and minimize the expansion and contraction of the plastic. The pipe will be supported along its entire length with good bedding.

Example Solution

After opening the spreadsheet and reading the read me page, go to the **INPUT** worksheet. Use the eraser to clear the input sheet. Enter the landowners name and location along with your name and date. (Remember entries are only allowed in the yellow cells).

Now, for cell B6, use the arrow to select the pipe diameter, type and pressure rating. From this data the OD, inside diameter (ID), wall thickness, are entered in the spreadsheet where needed. The pipe OD, material, type and pressure rating will automatically fill in from the nominal pipe dia. Information.

The next 3 cells input cells are for the design data. In cell B11, enter the design flow as 2 cfs for this system. The flow in gpm could be entered if preferred by using the pull down menu in C11. A pressure of 70 psi is entered into cell B12. In cell B13, the length is 1200 ft.

From the above entered data, the next 3 cells will automatically be calculated. The SDR, cell B14, shows 32.5. The B15 cell, design flow, will be 898 gpm. The velocity is 4.1 ft/sec in cell B16, this example. ***Unless a surge analysis is done the velocity should be kept less than 5 ft/sec*.**

To complete the Soil and Trench section, select the soil type from the drop down menu in B18. The soil weight in pounds/ft^3 is loaded into cell B19. If you have another soil weight, enter it into the B19 cell.

In cell B20, select the cover over the thrust blocks in feet, use the pull down menu on the right edge of the cell. Only the 4 values shown, 2ft., 3ft., 4ft., and 5ft., can be used to calculate the block size. For this example 30" is the planned cover depth. Since 30" is not listed, 2 ft is the best choice. It is better to underestimate the protection that the cover over the thrust block will give rather than overestimate it.

In our example, the maximum cover over the pipe, cell B21, would be 6 ft where the pipe is graded through the rise. This data is used to determine if the pipe will be crushed by the overburden soil load.

The final section of the worksheet is the External Effects on the Pipe. In cell B23, enter the internal vacuum pressure of 5 psi. In cell B24, enter **Ø** for the water table. The bedding, cell B25, is selected as fine grained w/ <25% coarse grained material from the pull down menu.

For cell B26, the compaction over the pipe is slight, which is less than 85% Standard Proctor. The type of backfill material, B27 cell, should have silt and clay mix from the pull down menu. In the load class, cell B28, select field equipment from the pull down menu.

There is a slight change in temperature around the pipe compared to the trench, so use a value of 5-15 degrees in cell B29.

Since the pipe is supported along the entire length, enter Ø for the unsupported free span length, in cell B30. A saddle contact angle for the support is entered in cell B31. Generally this should be greater than 90 degrees. A contact angle of 120º is a better value to use for saddles.

Figure 1. Input Worksheet with example data entered.

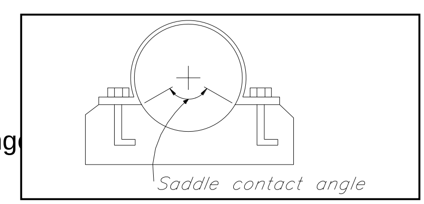
NEH Ch 52 Structural Design of Flexible Conduits

Plastic Pipe Version

Landowner	**Ch 52 Example**	**Designer**	**ldn**
Location	**Ea Washington**	**Date**	**4/1/2010**

(Use the eraser to clear all the input cells)

System Parameters		
Nominal Pipe Dia.	10 IPS -- 125	
Pipe OD	10.750	inches
Pipe material	PVC	
Pipe type	IPS	
Pipe pressure rating	125	psi
Design Flow	2.00	cfs
Expected Pressure in pipe	70	psi
Pipe Length	1200	ft
SDR	32.5	
Design Flow	898	gpm
Design Velocity	3.60	ft/sec
Soil and Trench		
Soil Type	Silt; uniform, inorganic	
Soil weight	109	lb/ft³
Cover over Thrust Blocks	2	ft
Maximum cover over pipe	6	ft
External Effects on the Pipe		
Internal vacuum pressure	5	lb/in²
Water table	0	depth above pipe -ft
Bedding	Fine grained w/ <25%coarse grained	
Compaction in backfill	Slight-<85%Standard Proctor	
Type of backfill material	Silt and clay mix	
Load class	field equipment	
Temperature change around pipe	15	degrees F chang
Unsupported free span	0	ft
Saddle contact angle	120	degrees



PRINT

Selecting the PRINT tab, located along the bottom of the spreadsheet, gives a detailed written summary of the pipeline based on the completed input sheet data. There is also, at the bottom of the page, an estimate of the friction loss based on the Hazen Williams Equation and a C value of 150.

The Print worksheet should be adequate documentation for most designs. However if more specific details are required, all other related worksheets are readable and printable for support documentation. These additional worksheets tabs are located along the bottom of the Chapter 52 spreadsheet.

Figure 2. Summary of the example as shown on the print worksheet.

Structural Design of Flexible Conduits

Ref - NEH Part 636, Chapter 52

Tn Example's pipeline is located at Central Wa. Computations by ldn. DATE: 4/1/2010

All inputs for this sheet are made on the input worksheet. All data to support this print sheet is located on the appropriate worksheet.

Pipe size and wall thicknesses are also located in PVC and HDPE data worksheets attached to this spreadsheet.

The pipe planned for this project is 10.75 inch (outside diameter), 125 psi, IPS, PVC.
The design flow rate is 2 cfs, which is 897 gpm. The velocity is 3.6 ft/sec.
The planned internal pressure is 70 psi on this 1200 ft long pipeline.

The soil weight for the backfill material is 108.5 lbs/ft3, and the pipe cover depth is 6 ft. The bedding material is planned to be Silt and clay mix. The backfill material is planned to be Fine grained w/ <25%coarse grained, with compaction to be Slight-<85%Standard Proctor.
The pipe selected has a wall thickness ok for the load.

Thrust blocks size table below is calculated based on 2 ft of cover over the block, with the planned pressure and backfill:

Pipe Direction Change	Size - ft2	Dimension on each side- ft
Tee	12.7	3.6
Reducer*	4.3	2.1
End of Line	12.7	3.6
Wye	12.7	3.6
Closed Valve	12.7	3.6
90 bend	18	4.2
45 bend	9.7	3.1
22 bend	5	2.2

* The reducer thrust block is computed assuming a change in the pipe size by 2" diameter.

Thrust blocks are always poured against and around the pipe and extends to undisturbed soil material.

Whenever there is flow in a pipe, there is a potential for surge when the flow stops or changes direction. With the pipe material, size and velocity of this line the surge pressure potential would be 46.8 psi. When added to the operating pressure in the line, the total pressure is 117 psi. This total pressure when compared to the pressure rating

of the pipe means that a rated pipe pressure is greater than surge pressure, no pressure relief is needed, min. valve dia. size is 3".
Even if there is not a need for a pressure relief valve, adding one at the highest pressure of the pipe is generally a good practice. Set valve to open at 5 psi below the pressure rating of the pipe (maximum).

Temperature changes in the pipe material can cause expansion and contractions. For the temperature change at your location with 15 degrees F of temperature change, the pipe length could change 1 ft for the length planned. This change in length, can be overcome by snaking the pipe in the trench when it is installed. The expansion length would be the additional amount needed to ensure that the line does not pull apart.

There are times where the pipe must be suspended above ground. The spacing of the supports is critical to ensure the pipe does not bend beyond allowable and over stress the material. The planned 0 ft support spacing for this pipe span is ok.

As the pipe is being laid it is allowable to bend it within the pipe section. The amount of bending allowed is based on a number of factors. With the planned pipe a 20 ft section can be curved a maximum of 1.1 ft.
This does not include any bending in the joint. The amount of joint deflection may be obtained from the pipe manufacturer. Solvent cemented or welded joints do not allow for joint deflection.

Loading on the pipe depends on a number of items, including bury depth, class of pipe, bedding and backfill to name a few.
This line has Fine grained w/ <25%coarse grained for bedding, Silt and clay mix soil for backfill, and is compacted the equilivent of Slight-<85%Standard Proctor. External loading on the pipe trench is from field equipment.

For this bedding, back fill and cover depth, the deflection on the pipe is estimated to be 1.78 %.
This amount of deflection should be less than 5%. For this pipe it is ok.
For buckling and strain on the pipe the wall thickness is ok for long term loading.
The pipe strain should not be more than 5% for HDPE or ABS material. The calculated strain is not calculated for PVC.
Pipe strain in PVC and HDPE is ok as long as the deflection is ok.

The friction loss in the pipeline based on flow, dia., length as planned is 4.5 ft, using Hazen Williams equation and a C of 150.

Any data entered or calculated outside of NRCS standards will need to be justified. All worksheets are protected, however a carriage return is the password to remove the protection. *Use caution when in unprotected mode, since it is easy to accidently overwrite an equation.*

REFERENCES, LITERATURE

USDA NRCS – UT (http://www.ut.nrcs.usda.gov/) - eFOTG

USDA NRCS - Part 636, Structural Engineering National Engineering Handbook, Chapter 52, Structural Design of Flexible Conduits

USDA NRCS – UT Technical Soil Services in Utah
http://www.ut.nrcs.usda.gov/technical/soils/index.html

Handbook of PVC Pipe; Design and Construction; 4th Edition, 2nd Printing – Uni-Bell PVC Pipe Association; 2655 Villa Creek Drive, Suite 155; Dallas, Texas 75234 (http://www.watermainbreakclock.com/handbook/) [as of 2/22/2010]).

Handbook of Polyethylene Pipe; The Plastics Pipe Institute; First Edition; Washington, DC
(http://www.plasticpipe.org/publications/pe_handbook.html [as of 2/22/2010])

Plastic Piping Handbook; David A Willoughby. POE; R. Dodge Woodson; Rick Sutherland; McGRAW-HILL

Filing Instructions. File in the Technical Notes notebook under ENG-210

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