CANDE-2015
INSTALLATION AND GUIDANCE

CONTENTS

1. INSTALLATION INSTRUCTIONS FOR CANDE-2015

Purpose.

The purpose of this instruction is to install the new CANDE-2015 DLL (dynamic link file) named "cande_dll.dll" into the CANDE executable folder containing the CANDE-2007 program with the 2011 upgrade. The new DLL, which replaces the old DLL with the same name, contains new executable logic for all enhancements to CANDE since 7/31/2011, which is the last TRB/NCHRP release date.

Instructions to install new DLL

1. Locate the CANDE executable folder currently in your computer, usually stored in the directory Program Files, or Program Files (x86). The default folder name is "CANDE 2007" even though it contains the 2011 upgrade.

2. Right click the new DLL, "cande_dll.dll" accompanying this instruction and obtain a copy.

3. Open the executable folder "CANDE 2007" and paste the new DLL into the file. **Answer yes to the question "Do you wish to replace old "cande_dll.dll" with new?**

4. **That's it! -- You're ready to go.**

Verification

After you run any CANDE input file, you may verify that you are using the new executable program by observing that the first line of output says;

```
*** WELCOME TO CANDE-2015(version 3/5/2015) ***
```

(Note, the previous version 1/30/2015 has been replaced with the above 3/5/2015 version, with greatly improved convergence algorithms for Mohr-Coulomb and Modified Duncan/Selig soil models.)

Peace of Mind

Do not worry! You can easily recover the old CANDE program by re-visiting the TRB website and downloading CANDE 2007 with the 2011 upgrade. Or you save the previous CANDE-2013 DLL prior to replacing it with the CANDE-2015 DLL.

2. WHAT IS CANDE- 2015

CANDE-2015 is the latest in the series of CANDE computer programs, which date back to 1976, and is dedicated to the structural design and analysis of buried culverts. The 2015 version of CANDE is an extension of the AASTO/TRB version CANDE-2007/2011 with seven new capabilities listed below.

1. **CONRIB pipe type.** This is a new pipe type in CANDE-2015 with modeling capabilities for rib-shaped reinforced/concrete cross-sections. Also, the concrete stress-strain model has the ability to model fiber reinforced concrete. (Industry sponsor Con/Span Bridge Systems)
2. **CONTUBE pipe type**. This is another new pipe type added to the pipe library that permits modeling circular-shaped concrete cross sections encased in fiber-reinforced plastic tubes spaced at uniform distances. (Industry sponsor Advanced Infrastructure Technologies)
3. **Link elements with death option**. Links are useful for connecting one beam-element group to another in either a pinned connection or fixed-moment connection. Also, the link element offers a death option that allows simulating strut removal, culvert erosion, and creation of soil voids. (Industry sponsors Contech Construction Products and MGK Consulting)
4. **Deeply corrugated steel structures**. CANDE's corrugated steel pipe type now includes the new AASHTO combined moment-thrust design criterion and new global buckling equation for deeply corrugated steel structures. Also, the plastic-penetration algorithm has been improved. (Industry sponsors Atlantic Industries and Contech Construction Products)
5. **Variable plastic profile properties.** The input data defining plastic profile section properties has been expanded to allow variable profile geometry around the pipe's periphery. This is useful for arch-shaped storm-water chambers that vary the plastic profile geometry from top to bottom. (Industry sponsors Advanced Pipe Services and Prinsco)
6. **Classical Mohr/Coulomb elastic-perfectly plastic model.** This traditional elastoplastic model is now included in the suite of available constitutive models that may be assigned to continuum elements to describe soil behavior. (Industry sponsors Contech Engineered Solutions and MGK Consulting)
7. **Modified Duncan/Selig soil model.** A modified version of the Duncan/Selig model is now available, which produces permanent deformations upon unloading similar to advanced plasticity models. No new material parameters are introduced into the new formulation; thus, the existing data base of Duncan/Selig parameters remains valid for the modified formulation. (Industry sponsors Contech Engineered Solutions and MGK Consulting)

Q & A

***Who sponsored the new capabilities*?** New capabilities and improvements in CANDE-2015 are provided gratis as a result of the industry sponsors noted above.

***Does CANDE-2015 work with all old input files*?** YES! All input files that worked with CANDE-2007/2011 or CANDE-2013 will work the same way with CANDE-2015.

How do I use the new capabilities? The CANDE-2015 User Manual provides complete batch-mode input instructions for the new capabilities written in red ink. The GUI input menu is not updated for the new capabilities -- see the discussion at the end of this document for working with the GUI.

3. NEW CAPABILITIES 2015 AND REFERENCES

Description of new capabilities in CANDE-2015	User Manual Chapter 5, Section number and (line marker)	Solution and Formulation Manual, Section No.
CONRIB pipe type. CONRIB has been added to CANDE's pipe-type library that provides the capability of modeling rib-shaped reinforced/concrete cross-sections as well as standard rectangular cross sections. Moreover, the concrete constitutive model has been extended to include the simulation of fiber reinforced concrete. (2013)	5.3.2 (A-2) and 5.4.5 (B-1 to B-6)	2.6
CONTUBE pipe type. This special pipe type provides the capability of modeling circular shaped concrete cross sections encased in fiber-reinforced plastic (FRP) tubes spaced at uniform distances. (2013)	5.3.2 (A-2) and 5.4.6 (B-1 to B-6)	2.7
Link elements with death option. Two simple options are, (1) connect any two nodes with a pinned connection; or, (2) connect two beam nodes with a fixed-moment connection. The link-element death option is an extremely useful capability allowing the removal of any link element and its forces at any specified load step. Also a special composite joining option for beam groups. (2013)	5.5.6.4 (C-4) and if composite 5.6.8 (D-2)	4.11 to 4.15
Deeply corrugated steel structures. Updated steel pipe type to accommodate the recently adopted AASHTO requirement for a combined moment-thrust design criterion that applies to deeply corrugated steel structures as well a new AASHTO equation to predict the global buckling resistance. These new design criteria may be activated at the user's discretion. (2013)	5.5.4.1 (B-1) and 5.5.42 (B-2)	2.2.2
Plastic pipe type variable profile properties. The plastic pipe subroutine has been revised to allow variable profile geometries around the structure. This applies to all types of plastic including HDPE, PVC, and PP. Useful for analyzing storm-water chambers. (2013)	5.4.3.4 (B-3, B3b)	2.4.3
Mohr/Coulomb plasticity model. The classical Mohr/Coulomb elastic-perfectly plastic model is now included in the suite of available constitutive models that may be assigned to continuum elements to describe soil behavior. Four material parameters are required to define the model: E, ν, c and φ. (2015)	5.6.9 (D-2)	3.7 (3.8)
Modified Duncan/Selig soil model. The new modified Duncan/Selig model produces permanent deformations upon unloading similar to advanced plasticity models. No new material parameters are introduced into the new formulation; thus, the existing data base of Duncan/Selig parameters remains valid for the modified formulation. The user has the option to use either the Original or Modified version.(2015)	5.6.4.1 (D-2)	3.58 to 3.59 (3.8)

4. USING THE GUI WITH CANDE-2015

The graphical user interface (GUI) works with CANDE-2015 in exactly the same manner as it works with the original CANDE-2007/2011 program except for utilizing the new capabilities developed after 2007. When dealing with any of the following new capabilities;

- CONRIB Pipe Type
- CONTUBE Pipe Type
- Link elements
- Deep corrugation design criteria for Steel Pipe Type
- Variable Profile geometry for Plastic Pipe Type
- Mohr-Coulomb elastoplastic soil model
- Modified Duncan/Selig model with plastic-like behavior

it must be understood that the GUI input wizard is unaware of these options. Consequently to utilize these new capabilities, the input data must be entered in the batch-mode. That is, from the File menu on the CANDE screen select "Open text input" and refer directly to the input instructions in Chapter 5 of the CANDE-2015 User Manual to enter the required data.

The GUI has two facets, pre-processing and post processing. Pre-processing is concerned with creating input data files, and post-processing deals with viewing the output files and graphically plotting the finite element mesh and structural responses. Both facets are discussed below with regard to how they interact with the new capabilities listed above.

Creating Input Files (pre-processing). The GUI interface menu offers two basic modes for creating an input data file as listed below.

1. Traditional batch input (choose File → Open Text Input)
2. Menu-driven input (choose File → New)

Mixing these two input methods is the easiest way to generate an input file that incorporates any of the new capabilities. For example, suppose we want to create an input file utilizing the CONRIB pipe type. The Menu-driven input screen does not have a selection choice for the CONRIB pipe type; however, we can choose the CONCRETE pipe type as a temporary surrogate. After all the remaining menu-driven input data is complete and the entire data file has been saved and stored, we reopen the data file with "Open Text Input" and refer to CONRIB pipe type in Chapter 5 of the CANDE-2015 user manual to replace the input lines of the surrogate pipe data with the required CONRIB input data. Said another way, this second step is a mini-batch-mode input process, only changing a few lines of input. The above process also applies to CONTUBE. Note that the GUI-generated line tags ending with double exclamation marks for the surrogate CONCRETE pipe type, such as B-1.Concrete!!, can be removed so that CONRIB or CONTUBE input data begins in column 1 in accordance with the CANDE-2015 User Manual.

As another example, consider creating a Level 3 input file incorporating link elements. From the element input instructions in Chapter 5 (C-3 lines), we observe that the link element nodal

connectivity is defined exactly like an interface element so that we may use the interface element as a surrogate to enter nodal connectivity in the Menu-driven screens. Later when we switch to Open Text Input, the special link element connection code and death option may be typed in the specified columns.

Menu-driven input for the Modified Duncan and Duncan/Selig soil models is straight forward because no surrogate name is needed. We simply select the original Duncan/Selig model (ITYP = 3) and supply data in the usual manner whether it be canned soil parameters like SW90 or USER defined parameters. Next we switch to Open Text Input and insert one new data entry, NEWDS = 1, as described on line D-2 of the Duncan and Duncan/Selig input data in the CANDE-2015 User Manual. If this new data item is not entered the Original formulation is employed.

Finally for the new Mohr-Coulomb elastoplastic model (ITYP = 8), the linear elastic soil model (ITYP = 1) may be used as a surrogate in the Menu-driven input screen. After switching to the batch input mode, we remove the GUI-generated line tags for the surrogate soil model and enter the Mohr-Coulomb data following the directions for lines D-1 and D-2 in the user manual.

In summary, this two-step process of generating menu-driven input data followed by a mini-batch-mode correction is a very effective way of creating input files for all the new capabilities.

Viewing Output Files (post-processing). After a successful CANDE run, the View tab on the GUI tool bar includes the viewing options listed below.

- Output Report (CANDE)
- Mesh Plot
- Graphs

As discussed next, these viewing options have different implications with regard to displaying the output from the new capabilities.

Output report (CANDE). The Output Report, which is the most important document, is a complete print file generated by the CANDE-2015 program and is navigable by means of an interactive table of contents. Since the table of contents and the printed output is generated directly from the CANDE-2015 Engine, there is no loss of data or ambiguity with regard to the new capabilities. For example, the table of contents identifies these capabilities by name, such as "CONRIB", CONTUBE" and "Link", just as it does with all other pipe types and element types. Similarly, the output identifies the Mohr-Coulomb model and parameters by name as well as which version of the Duncan/Selig soil model is employed, Original or Modified. Therefore the new capabilities are displayed perfectly and seamlessly with regard to viewing the Output Report**.**

Mesh plots. The GUI mesh plot viewing option, which allows plotting finite element mesh topology as well as displacements, and soil stress/strain contours, is fed by a XML plot file developed especially for the GUI. Consequently, the words "CONRIB" "CONTUBE" or "Link" do not appear in the input or output screens for selecting data to be plotted. Instead the generated XML plot files have been assigned alias names as follows;

- Each CONRIB pipe-type group number is labeled as a CONCRETE group number.
- Each CONTUBE pipe-type group number is labeled as a CONCRETE group number.
- Each "link" element is labeled as an "interface" element with its unique element number.

When mesh elements using the Mohr-Coulomb soil model are "clicked" on screen, the soil model name is shown as "Hardin", which is a surrogate name borrowed from an old legacy soil model still available in CANDE-2015. However, the actual soil model is easily verified by checking the element's material number with the soil model information printed in the output report. Similarly, if the element's soil model is identified as Duncan or Duncan/Selig, the distinction between the original and modified formulation is easily verified by checking the element's material number with the soil model information printed in the output report.

With the above understanding, the new pipe types, link elements, and soil models have full access to the GUI plotting capabilities. If there is more than one pipe group, the user identifies the pipe type by its unique group number. Similarly the user identifies link elements (versus interface elements) by the unique element number, and soil models with unique material numbers.

Graphs. The GUI graph plotting option is dedicated to viewing structural responses of any pipe-type group wherein the plot data is obtained from another XML plot file developed for the GUI. Using the same alias names noted above, each CONRIB and CONTUBE pipe-type group number is labeled as a CONCRETE group number. Therefore, using the CONCRETE label with unique pipe group numbers, the CONRIB and CONTUBE structural responses may be plotted just like any other pipe type. (Hint -- If the "Graph" option does not seem to work, rerun the input file under then "Open" option instead of the "Open Text Input" option.)