Parametrical intelligent design of steel bridges based on APDL language

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Abstract. Bridge is a hub project of traffic engineering, and it also reflects the comprehensive national strength of a country and a region, such as economic strength, science and technology, productivity development and so on. Parametric intelligent design is an inevitable trend of bridge engineering’s development under the existing knowledge system. A parametric static and dynamic analysis software has been developed for two types of typical steel bridges -- steel tube arch bridges and steel truss bridges based on APDL language. It can do the intelligence design work automatically for those bridges, which including the preprocessing work and the postprocessing work, such as the input of material data, section data, structure size, loads and constraints, and the output of force results, stress results, capturing images, and writing the design report file. Even the designer who is not professional can do the preliminary design work of a same type bridge quickly and easy with this software.

1. Introduction
Transportation is a basic industry and an important foundation of national economy, and bridge engineering plays the most important role in a transportation system. Lots of steel bridges have been built in recent years in China and a lot of bridge design work still needs to be done in future. According to the classic design method, each bridge with different span or bridge width and other data slightly changed should be modeled and calculated respectively. Usually, every bridge design work needs to input pre-processing data manually, including material data, section data, node coordinates, elements information, loads and constraints etc., which will waste a lot of time on repetitive work, make simple work complicated, and even become an issue for the design quality and project schedule.

At the same time, Most existing bridge design software are not universalizable enough for the same type bridges with different sizes, and lack of parametric intelligent design module. When the bridges have different material parameters, geometric parameters or load parameters, the design work have to be done respectively. Therefore, the development and research of parametric intelligent design software for bridges can improve the speed and efficiency of bridge design work dramatically, and reduce the cost of bridge design too.

A parametric intelligent design software is developed based on APDL language for two types steel bridges—typical steel tube arch bridges and steel truss bridges in this paper work. It can design lots of same-type bridges in a few minutes based on one sample, do the static and dynamic analysis quickly, compare the bearing capacity of each bridge, calculate the amount of engineering materials, and write the design report file automatically.

This intelligent design software works well during the period of selecting bridge design scheme and the preliminary design of these two types of steel bridges, which can reduce the difficulty of design
work and improve the design efficiency significantly, and has great engineering practical significance and application prospects.

2. Intelligent design functions

2.1. Intelligent pre-processing for steel tube arch bridges

Arch axis coordinates are calculated and obtained automatically in the intelligent design model for steel tube arch bridge based on APDL language, and the static and dynamic analysis data are parameterized in both of pre-processing module and post-processing module. The main contents include:

2.1.1. Parameterization of bridge configuration data

the span, rise-span ratio, number of joints and width of bridge deck of the same bridge type are all inputted with parameters, which can be changed at the beginning of the software (or inputted in a dialog box) easily. The codes of a real bridge model are shown as follows:

* SET, spanl, 35120  ! Spanl: the span of bridge
* SET, SGF, spanl / 9  ! SGF: the vector span ratio (1/9)
* SET, wide, 2000    ! Wide: the bridge deck width
* SET, JJS, 6       ! JJS: the number of longitudinal joints
* SET, GJX, 1800    ! Horizontal distance of arch foot joint
* SET, ZGDZSX, 800  ! Main arch rib top z - direction contraction distance

Usually, the joint distance between the bearing and the second joint of the main arch rib should be reduced properly. The parameter GJX is set as the horizontal distance between the bearing node and the second node, which is 1.8m away from the arch foot node here, and the joint distance between other adjacent nodes of the main arch rib is equal. The parameter ZGDZSX is set as the maximum reduced transverse distance between the top of two main ribs, because the lateral anti-overturning stability of the arch bridge can be improved effectively by reducing the transverse distance.

2.1.2. Parameterization of node coordinates

The 3D coordinates of all main arch nodes are expressed as parameters, and are obtained automatically according to the catenary mathematical equation, while the vertical coordinate gy1(i) of arch rib nodes are shown as follow:

\[ gy1(i) = 4*sgf* (spanl - zgx1(i))* zgx1(i)/spanl/ spanl \]  (1)

After the top distance is reduced by ZGDZSX, the transverse z-coordinate of the two arch ribs nodes are Zgz1(i) and Zgz2(i) respectively:

\[ Zgz1(i) = (zgdzsx)*(spanl - zgx1(i))/spanl \]  (2)
\[ Zgz2(i) = wide - (zgdzsx)*(spanl - zgx1(i))/spanl \]  (3)

A arch bridge can be modelled in two minutes based on a model sample of a same type bridge, which could have different span, different sections, different rise-span ratio, different joint distances, different bridge width and transverse reduced distance ZGDZSX, which are shown as figure 1, while B model established by modifying four parameters of model A.

| A: span=36m, wide=4m, sgf=1/12, zjdzsx=2.5m | B: span=60m, wide=8m, sgf=1/8, zjdzsx=5m |
|-------------------------------------------|-----------------------------------------|

Fig.1 B modelled in 2 minutes
2.2. Intelligent post-processing

2.2.1. Result images captured and saved in a file automatically

The result images are captured and stored in a parameterize-named file automatically, including force images, stress images and deformation images etc.. The codes are shown as following:

```plaintext
PLnSOL, S.y, 0,1,0
*get,snmax,PLnSOL,0,max !Gets the range of values
*get,snmin,PLnSOL,0,min
/CONT,1.15,snmin..snmax/1.05 !Adjust the scale of image
/RGB,INDEX,100,100,100, 0 !Adjust color
/replot
/image,save,'E:\output\sycrack%xtip%t%shghou%\',bmp !Save Image
```

2.2.2. Result data extracted and written into a file automatically

The result data are extracted and written into a parameterize-named file automatically, including force data, stress data and deformation data etc., shown as Figure 2. The codes are shown as following:

```plaintext
ETABLE,ZZL,LS,4        ! ZZL: stress of beam considering Z-axis bending moment
*GET,NODESTR(1,3),ELEM,CURELEM,ETAB,ZZL! the array assignment 
*CFOPEN,E:\output\ZongHdt%xtip% ',TXT,,APPEND !Open a file
VWRITE,NODESTR(1,3) !Write data
*CFCLOSE !Close the file
```

The result data can also be written in a specified report file automatically by the following command:

```plaintext
~eui,'package require ansys'
~eui,'ansys::report::setdirectory "crack_report"
~eui,'ansys::report::outputcapture {crack Listing %xtip%t%shghou%rs} "prrsol"
```

Figure 2. Result data written into the specified report file

2.2.3. Bearing node forces written into a file automatically

Bearing node forces are extracted and written in a specified file automatically, which can obtain the 3-axial resultant forces from the superstructure to the substructure under the specified loads quickly. When considering dead load only, the vertical total force is total weight of the superstructure.

2.2.4. Material quantities calculated automatically.

Element volumes/length and total length of a element group can be obtained by APDL commands. The total weight of a element group or whole bridge structure is gotten from the length, the cross-section area and the material density, and written in a specified file automatically. Compared with traditional design methods, the comparison of material quantities/economy could be finished easy and rapidly between different bridges, so that substantial time and human resources are saved. The main codes are shown as following:

```plaintext
*GET,CURleng,ELEM,CURELEM,leng! Get an element length
*SET,fgzleng,fgzleng+fgleng(i)! Set the total length
*SET,CURELEM,ELNEXT(CURELEM)! Point to the next element in group
```
2.3. Intelligent design for steel truss bridges
A static and dynamic analysis software is developed based on APDL for typical steel truss bridges, which has the same parameterize-modelling method as that described in 2.1 and 2.2. The type of beam section can be I-shaped, rectangular, circular-pipe beam etc. A new bridge model will be built by changing four data based on a model sample simply and quickly, the four data locate at the beginning of the model file, which are shown as following:

- *SET,spanl,35400 !span
- *SET,gdh,3200 !height of a truss
- *SET,wide,2000 !Lower chord center spacing
- *SET,jjs,12 !Nodal number

The model of bridge B can be built only by modifying four data based on bridge A’s model, shown as Figure 3:

![Bridge Models](image)

A: span=36m, wide=4m, height=3.5m, joints account=6
B: span=60m, wide=8m, height=6m, joints account=10

Figure 3. Bridge B modelled in 2 minutes by changing four data

3. Conclusion
The intelligent design software bridges are successfully developed for two common steel bridges—steel tube arch bridges and steel truss bridges based on APDL language, which can do the dynamic and static analysis of several same-type bridges in a very short time, evaluate material quantities and write the required results into a specified file automatically.

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