Application of Mamdani and Sugeno Fuzzy Toward Ready-Mix Concrete Quality Control

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Abstract. The value of concrete compressive strength based on several methods of acceptance requirements of concrete in Indonesia to obtain a more economical concrete quality is recommended using SNI 03-2847-2002 rules as a reference in the evaluation and quality control of concrete. Fuzzy logic is different from ordinary digital logic, where the usual digital logic only recognizes two condition that is "yes" or "no". While Fuzzy logic imitate the way of human thinking by using the concept of the pseudonym of a value. The Mamdani type and Sugeno type is resulted in the same decision, although there was a difference in the calculation of the final result but still within the same range of manual calculations with the calculation with the help of MATLAB. Both fuzzy can be applied in determining the quality of concrete because it produces the same decision. Although both fuzzy method can be used in determining the quality but the more recommended is the Mamdani type because Mamdani type result of calculation is closer to the actual result, and while there is input change is entered then the end result will change but Sugeno type while input change value is not too big the change then the end result also there will be no change.

1. Introducing

The term Ready-mix Concrete is familiar to Engineers, because almost all buildings and infrastructure use concrete as the base material of the building. Concrete is a major component of a building structure consisting of cement, coarse aggregate, fine aggregate and with additional water or no additives. As chemically formed materials, the manufacturing aspect is very influential to the final quality of the concrete produced. Rapid advances in the field of construction must be balanced with technological advances as a means of support. The purpose of supporting technology applied is to minimize problems that will occur in the field.

According to SNI 03-443-1997 defining Ready-mix concrete is a concrete mixed in a stationary stirring machine or in a stirrer truck, and delivered to fresh concrete consumers. The use of concrete in the building can save expenses because the price is affordable, can be made in accordance with the desired shape and size and can be combined with steel reinforcement. The sense of interest in the use of concrete eventually resulted in many types / qualities of the concrete itself.

To get a good mixture, easy to do and quality in accordance with the desired, then performed a procedure called mix design process. Mix design is done to determine the proportion of concrete aggregate concrete produced so that the concrete in accordance with the quality that has been planned. Type / quality of concrete is obtained from concrete strength test results per each quality.

Comparison of strong value of concrete has been frequently studied, one example is the comparison of concrete compressive strength value based on some methods of concrete acceptance
requirements in Indonesia [1], in the journal it is concluded that to get a more economical concrete quality is recommended to use SNI 03-2847-2002 as reference in evaluation and quality of concrete.

2. Methodology
Fuzzy logic is different from ordinary digital logic, where the usual digital logic only recognizes two conditions that is yes or no. While Fuzzy logic mimics the way of human thinking by using the concept of the disguised nature of a value. Fuzzy logic is widely used in various applications such as the segway system on robot phones [2], in the journal explained how to make a control system of robot mobile phones. The robot moves forward, backward and turn which is controlled by body movement. Application of other Fuzzy logic on financial analysis systems[3] and extensions of multicriteria analysis in pairs under the Fuzzy environment [4].

The application of Fuzzy logic comparisons has also been used for research among other comparisons of Fuzzy logic to predict market prices in Egypt [5]. This journal outlines the fundamental differences between Fuzzy Mamdani, Sugeno and Adaptive Neuro - Fuzzy Inference System (ANFIS) techniques. This system can be used to predict the weekly price of Egyptian market funds. The application results show that the model ANFIS is better than Mamdani and Sugeno.

Fuzzy logic in other applications is Mamdani and Sugeno comparison for breast cancer risk system[6] and application of Mamdani, Sugeno and Tsukamoto method comparison for energy reduction system on air conditioning[7]. In the journal analysis and comparison of Mamdani, Sugeno and Tsukamoto methods to find the best method in reducing the electrical energy consumption of AC by using room temperature and humidity as input variable and compressor speed as variable output. The experimental results show that the best method of reducing the electrical energy consumption of AC is the Tsukamoto method, where the average electrical energy efficiency is achieved up to 74.2775%. The Mamdani method is often known as the Max-min method. This method was introduced by Ebrahim Mamdani in 1975. To get the output, it takes 4 stages

a. The establishment of the Fuzzy Set
   In the Mamdani Type, both input and output variables are divided into one or more Fuzzy sets.

b. Application Function Implications
   In the Mamdani Type, the implication function used is min.

c. Composition of Rules
   There are three methods used in conducting Fuzzy system inference, that is max, additive and probabilistic OR (PROBOR). The reasoning with the Sugeno type is similar to Mamdani reasoning, it's just that the (consequent) output of the system is not a Fuzzy set, but rather a constant or a linear equation. This method was introduced by Takagi-Sugeno Kang in 1985, so this method is often also called the TSK method.

d. Affirmation (DeFuzzy)
   The input of the Defuzzification process is a Fuzzy set derived from the composition of Fuzzy rules, while the resulting output is a number in the Fuzzy set domain. So if given a set Fuzzy within a certain range, then it should be taken a certain crisp value as output.

In the development of the construction itself there is an important role of the concrete, but consumers still have to know what are the advantages and disadvantages of concrete so that consumers can decide whether to use Ready-mix concrete for the building or even more using the old way that is by manual. Here is a comparison between the advantages and disadvantages of concrete are:

| No | Excess | Deficiency |
|----|--------|------------|
| 1  | High compressive | Tends to be weak to tensile |
| 2  | Low price | If already formed (hard) difficult to change again |
| 3  | Composite materials easy to understand | Implementation requires Coarseness, supervision and a high work ethic |
| 4  | Easy to process | High density of concrete |
The process of finding results from the application of methods in determining the quality of Ready-mix concrete can be seen in the research framework.

**Figure 1.** Research Framework

### 3. Results and Discussion

3.1. Application

Application of concrete data as a consideration to determine the quality of concrete into computer application program using MATLAB version 6.1. In this research, the analysis uses 2 methods of fuzzy namely Mamdani method and Sugeno method which includes several stages the same is Fuzzification process, inference process and Defuzzification process [8][9][10].

3.2. Testing Results

System testing aims to obtain validation of data used as system design and compare it with the results of manual calculations from the use of toolbox MATLAB [11][12].

3.3. Mamdani Type

The following is performed on 10 data samples using Mamdani Type.

a. **Sample 01**
   
   Fine Agg sludge content = 5.13 Fine Agg moisture = 7.68 Coarse Agg mud content = 1.11 Coarse Agg water content = 1.82 Rules are formed = R1, R2, R3, R4 Output Mamdani = 6.4 (feasible) Output Sugeno = 5.9 (feasible)

b. **Sample 02**
   
   Fine Agg sludge content = 5.93 Fine Agg water content = 9.15 Coarse Agg mud content = 1.83 Coarse Agg water content = 2.32 Rule formed = R77, R78, R80, R81 Output Mamdani = 1.12 (not feasible) Output Sugeno = 3.32 (not feasible)

c. **Sample 03**
   
   Fine Agg sludge content = 3.93 Fine Agg moisture = 6.44 Coarse Agg mud content = 1.52 Coarse Agg water content = 1.45 Rules are formed = R73, R74, R76, R77 Output Mamdani = 1.25 (not feasible) Output Sugeno = 3.58 (not feasible)

d. **Sample 04**
Fine Agg sludge content = 5.18 Fine Agg moisture = 7.10 Coarse Agg mud content = 1.63 Coarse Agg water content = 1.17 Rules are formed = R74, R75, R77, R78 Output Mamdani = 1.85 (not feasible) Output Sugeno = 3.95 (not feasible)
e. Sample 05
Fine Agg sludge content = 6.59 Fine Agg moisture = 7.45 Coarse Agg mud content = 1.39 Sugeno = 3.34 (not feasible)
f. Sample 06
Fine Agg sludge content = 7.45 Fine Agg moisture = 6.95 Coarse Agg mud content = 1.54 Coarse Agg water content = 1.86 Rule formed = R75, R78 Output Mamdani = 1.25 (not feasible) Output Sugeno = 1.58 (not feasible)
g. Sample 07
Fine Agg sludge content = 5.23 Fine Agg moisture = 7.76 Coarse Agg mud level = 0.79 Coarse Agg water content = 1.57 Rule formed = R56, R57, R59, R60, R65, R66, R68, R69 Output Mamdani = 1.03 (Not Feasible) Output Sugeno = 2.86 (Not Feasible)
h. Sample 08
Fine Agg sludge content = 4.72 Fine Agg moisture = 6.44 Coarse Agg mud content = 1.17 Coarse Agg water content = 2.25 Rules are formed = R65, R66, R68, R69, R74, R75, R77, R78 Output Mamdani = 2.69 (Not Feasible) Output Sugeno = 4.76 (Not Feasible)
i. Sample 09
Fine Agg sludge content = 4.63 Fine Agg moisture = 7.33 Coarse Agg mud content = 1.12 Coarse Agg water content = 2.45 Rules are formed = R65, R66, R68, R69, R74, R75, R77, R78 Output Mamdani = 2.25 (Not Feasible) Output Sugeno = 4.07 (Not Feasible)
j. Sample 10
Fine Agg sludge content = 4.83 Fine Agg water content = 8.09 Coarse Agg mud content = 1.26 Coarse Agg water content = 2.70 Rule formed = R68, R69, R71, R72, R77, R78, R80, R81 Output Mamdani = 3.03 (Not Feasible) Output Sugeno = 3.58 (Not Feasible)

Table 2. Comparison of Manual Calculations between Mamdani Programs

| No | Fine Agg Mud | Fine Agg Water | Coarse Agg Mud | Coarse Agg Water | Quality | Manual | Program |
|----|--------------|----------------|---------------|-----------------|---------|--------|---------|
| 1  | 5.13         | 7.68           | 1.11          | 1.82            | Not Feasible | 3.42   |
| 2  | 5.93         | 9.15           | 1.83          | 2.32            | Not Feasible | 1.99   | 1.12    |
| 3  | 3.82         | 6.55           | 1.52          | 1.45            | Not Feasible | 2.03   | 1.25    |
| 4  | 5.18         | 7.10           | 1.63          | 1.17            | Not Feasible | 2.06   | 1.85    |
| 5  | 5.59         | 7.45           | 1.39          | 2.59            | Not Feasible | 1.95   | 1.25    |
| 6  | 7.45         | 6.95           | 1.54          | 1.86            | Not Feasible | 1.97   | 1.25    |
| 7  | 5.23         | 7.76           | 0.79          | 1.57            | Not Feasible | 3.09   | 1.03    |
| 8  | 4.72         | 6.44           | 1.17          | 2.25            | Not Feasible | 4      | 2.69    |
| 9  | 4.63         | 7.33           | 1.12          | 2.45            | Not Feasible | 4.14   | 2.25    |
| 10 | 4.83         | 8.09           | 1.26          | 2.70            | Not Feasible | 3.55   | 3.03    |

Table 3. Comparison of Manual Calculations between Sugeno Programs

| No | Fine Agg Mud | Fine Agg Water | Coarse Agg Mud | Coarse Agg Water | Quality | Manual | Program |
|----|--------------|----------------|---------------|-----------------|---------|--------|---------|
| 1  | 5.13         | 7.68           | 1.11          | 1.82            | Not Feasible | 3.02   |
| 2  | 5.93         | 9.15           | 1.83          | 2.32            | Not Feasible | 2      | 3.32    |
| 3  | 3.82         | 6.55           | 1.52          | 1.45            | Not Feasible | 2      | 3.58    |
| 4  | 5.18         | 7.10           | 1.63          | 1.17            | Not Feasible | 2      | 3.95    |
| 5  | 6.59         | 7.45           | 1.39          | 2.59            | Not Feasible | 2      | 3.34    |
4. Conclusion

From table 4 and 5 it can be seen that manual calculation with the help of MATLAB program both Mamdani type and Sugeno method produce the same decision, although there is difference calculation of final result but still in same range between manual calculation with calculation with MATLAB help. Both fuzzy methods can be applied in determining the quality of concrete because it produces the same decision. Although both types can be used in determining the quality but the more recommended is the Mamdani type because Mamdani type result of calculation is closer to the actual result, and Mamdani type if there is input change is entered then the end result will change but Sugeno type if input change value is not too big the change then the end result also there will be no change.

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