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AN EXPERT SYSTEM FOR WELL MODEL DESIGN SPECIFICATIONS

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Abstract
This work centered on adapting expert system in modeling design specifications for well construction. It came about by designing an interactive interface through a special Integrated Development Environment (IDE). The IDE was developed by programming well design parameters ranging from hydraulic parameters to quantitative material characteristics. Operation of the interactive interface was simplified to nearest minimum data entry i.e. height of well, H, and thickness of chamber, C; which served as the required operational design parameters. Inputs of the designed entry parameters in IDE were able to generate every required design specification outputs. Series of generated outputs from the developed expert system were put to test by randomly selecting design specifications at all three levels of "C" i.e. 1 mm, 2 mm and 3 mm. The output design specifications at each level of "C" were correlated at randomly selected level of "H". Each correlation evaluation was found to have R^2 of 1. This affirmed that the specification outputs were precise and reliable.

Keywords: Well, Model Design, Expert System, IDE, Model Specifications.

Introduction
The first set of expert systems were created in the 1970s which later become more prominent in circulation in 1980s (Zhao et al., 2020). Inference engine and the knowledge base were identified as the two major components of an expert system (Nwigbo & Agbo, 2011). Expert systems were among the first truly successful forms of Artificial Intelligence (AI) software (Wei et. Al., 2020; Kuman

& Jain, 2012). Artificial intelligence (AI) concerned with designing intelligent computer system that changes something from useful to something essential (Lake et al., 2017; Duke & Regenie, 2006; Peter, 2014). One area of AI that can claim a large measure of responsibility for the current heightened AI awareness is Knowledge Based Expert System (KBES), computer programs that embody human expertise (Davenport, 2020; Buchanan & Shortliffe, 2011). It is one of the important research fields in Artificial Intelligence for problem solving (Reid & Polanyi, 2007). It is the first AI technology to widely impact business and industry which offers much practical use and commercial potential (Davenport, 2020). Knowledge Based Expert systems unambiguously succor the computer to assist in solving non-perfectly structured and non-deterministic problems such as in design activities including evaluation and modeling, synthesis and decision-making process (Kuman & Jain, 2012). Therefore, development of an Expert System requires a tool that will provide for better means of knowledge acquisition, inference mechanism and user interface. AI based expert system has been made used in several field in solving many complex problems. Ogunlela and Awoniyi (2020) employed an expert system to design for rural water supply management and established the interactive instructiveness of an expert system with human expert thereby making decisions by providing solution and simultaneously monitor a pre-designed plan as an alternative to human expert. The decision making process of an AI was also affirmed by Akhund et al. (2014); and Yelapure and Kulkarni (2012). Pakinson and Longstaff (2015) resolved error mapping in machine using automated planning expert system for architectural design. AI was successively used by Ramesh et al. (2012) to simulate hydraulic parameters for water distribution networking. Abdullah et al. (2020) also made use of as a meteorological tool in forecasting temperature. He concluded that expert system is perfect for providing solution in his domain. An expert system serves as a helper to human expert by making use of basic information as inputted from human to resolve complex problems within a shorter time Lindsay et al. (2004). Analytically, well model has been successively used in reservoir simulation (Demetri & Farouq, 2004) but the modeling for this work incorporated sand and gravel filtration techniques as it is obtained in underground water percolation misery. This technique was made used in slow sand filtration as developed by Centers for Disease Control & Prevention (CDCP) (2014); Bauer et al., (2011); and Aslan & Cakici (2007).

This work aimed at designing an expert system for a typical structural well model design. It came about through designing the basic parameters required for the model formulation; formulate the quantitative materials requirement as a representative for underground water movement; generalizing the well prototype design criteria and finally design of an interactive interface for the general well model requirement for a valid test of output. The scope of this work entailed the basic fundamental principles parameters required in in designing a typical well model. This ranges from its dimension to its capacity and hence provided the fundamental perquisite for development of a typical well model. The model considered three major filter materials namely, sand, gravel and fibres as representative of porous medium for water percolation, filtration, and seepages of underground water in a typical well. The core secretes of this model inculcated inference mechanism with an accurate user interface embedded in module for information acquisition. The end product of this system could as well be employed in bridging the abstract form misery of the underground water discharge to realism. Investigation of hydrogeological conditions of well could be made simple and breakdown physical realism and at the same time aid teaching for drawing water quality test, filtration, well construction among others.

Methodology

The methodology employed in this work involved formulating and defining basic parameters of a typical well model, designing sand, gravel and fibre filter requirement as representative for underground water movement medium, formulating general well prototype capacities (volumetric and weight capacity) and design an interactive interface for general well prototype requirement for a valid test of output. The well model was designed to have five (5) major components; Source water, Filtration chamber, Water cavity, Pump, and the Testing chamber.

Design Modeling Analysis

Design for Filtration chamber

The design for filtration chamber was determined as reported by Ogunlela and Awoniyi (2020). Filtration chamber comprised of three major components; primary filtration chamber (sand filter column chamber), secondary filtration chamber (gravel filter column chamber) and tertiary filtration chamber (fibre filter column chamber).

Sand filter column chamber

Designed models for sand chamber construction specifications were given in equation (1) and (2)

$h_{sc} = \frac{1}{2}H$ (1)

$b_{sc} = \frac{1}{2}H$ (2)

where h_{sc} is the height of the sand column, b_{sc} is the width of the sand column, and H is the height of the sand chamber.

Gravel filtration column chamber

Designed models for gravel chamber construction specifications were given in equation (3) and (4)

$h_{gc} = h_{sc} - c$ (3)

$b_{gc} = \frac{2}{3}H$ (4)

where h_{gc} is the Height of gravel column, b_{gc} is the width of gravel column, c is the thickness of the chamber and H is the height of the gravel chamber.

Fibre filter column chamber

Designed models for fibre filter chamber construction specifications were given in equation (5) and (6)

$b_{fc} = H_{sc} - 2c$ (5)

$b_{fc} = \frac{1}{6}H$ (6)

where b_{fc} is the width of fibre column, h_{fc} is the height of fibre column and c is the thickness of the chamber.

Design for Water cavity chamber

Designed models for water cavity chamber construction specifications were given in equation (7) and (8)

$h_c = H_{sc} - 3c$ (7)

$b_{wc} = \frac{1}{12}H$ (8)

where h_c is the height of water cavity, b_{wc} is the width of water cavity and c is the thickness of the chamber.

Design for Perforated Chambers

Designed models for perforated chamber construction specifications were given in equation (9) and (10)

$h_{pg} = \frac{1}{3}H$ (9)

$h_{pf} = \frac{1}{3}H$ (10)

$h_{pc} = \frac{1}{6}H$ (11)

where h_{pg} is the perforated height of gravel, h_{pf} is the perforated height of fibre, and h_{pc} is the perforated height of water cavity.

Design for quantity of filter materials

The design and calculation for each of the filter materials used in the well model, the volume of sand filter, gravel filter and fibre filter was determined from the basic hydraulic principles adopted by Awoniyi, Adeniran and Owoeye (2020):

Quantity of Sand Filter.

$$b_s = b_{sc} - 2C \quad (12)$$

$$V_S = \frac{\pi}{4} h_{sc} \left(b_s^2 - b_{gc}^2\right)$$

$$V_s = (\pi \frac{(b_s - 2C)^2\, h_{sc}}{4} - \frac{\pi}{4} b_g^2\, h_{sc})$$

$$V_s = \frac{\pi}{4} h_{sc} \left((b_{sc} - 2C)^2 - \left(b_{gc}\right)^2\right) \quad (13)$$

where:

b_s is the width of sand, b_{sc} is the width of sand column, h_{sc} is the height of sand column, C is the thickness of the chamber, $b_g$is the width of gravel, , b_{gc} is the width of gravel column.

Quantity of gravel filter.

$$b_g = b_{gc} - 2C \quad (14)$$

$$V_{gravel} = \frac{\pi}{4} h_{gc} \left(b_g^2 - b_{fc}^2\right)$$

$$V_{gravel} = \frac{\pi}{4} h_{gc} \left((b_{gc} - 2C)^2 - \left(b_{fc}\right)^2\right) \quad (15)$$

where b_g is the width of gravel, b_{gc} is the width of gravel column, C is the thickness of the chamber, b_{fc} is the width of fibre column, h_{gc} is the height of gravel column.

Quantity of Fibre filter.

$$b_f = b_{fc} - 2C \quad (16)$$

$$V_{fibre} = \frac{\pi}{4} h_{fc} \left(b_f^2 - b_{wc}^2\right)$$

$$V_{fibre} = \frac{\pi}{4} h_{fc} \left((b_{fc} - 2C)^2 - (b_{wc})^2\right) \quad (17)$$

where b_f is the width of fibre, b_{fc} is the width of fibre column, C is the thickness of chamber, h_{fc} is the height of fibre column, b_{wc}^2 is the width of water cavity.

General design for filter materials

$$\rho = {}^{M}/_{V} \tag{18}$$

$$M_s = \rho_s \times V_s$$

$$M_s = \rho_s\, h_{sc} \frac{\pi}{4}\left((b_{sc} - 2C)^2 - (b_{sc})^2\right) \tag{19}$$

$$M_g = \rho_g\, h_{gc} \frac{\pi}{4}\left((b_{gc} - 2C)^2 - \left(b_{fc}\right)^2\right) \tag{20}$$

$$M_f = \rho_f\, h_{fc} \frac{\pi}{4}\left((b_{fc} - 2C)^2 - (b_{wc})^2\right) \tag{21}$$

where M_g is the mass of gravel, M_f is the mass of fibre, h_{sc} is the height of sand column, $h_{gc}$is the height of gravel column, $h_{fc}$is the height fibre column, $b_{sc}$is the width of sand column, b_{gc} is the width of sand column, $b_{fc}$is the width of fibre column, b_{wc}^2 is the width of water cavity.

Water capacity

$$\frac{\pi H_c}{4}\,\lfloor D_c - 8C\rceil^2 - \left[V_s + V_g + V_f\right] \tag{22}$$

where H_c is the height of the cavity, volume of sand

DESIGNED PROGRAM FOR THE WELL MODEL

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REM: "EXPERT SYSTEM FOR WELL MODEL DESIGN"
10 CLS: PRINT
20 PRINT "EXPERT SYSTEM FOR WELL MODEL DESIGN"
30 PRINT "PROGRAM TO STIMULATE SPECIFICATIONS FOR A WELL MODEL"
40 DIM H AS SINGLE, C AS SINGLE, Y AS STRING, N AS STRING
50 PRINT "H = height of well model"
60 PRINT "C = thickness of well chamber"
70 PRINT "hsc = height of sand column"
80 PRINT "hgc = height of gravel column"
90 PRINT "hfc = height of fibre column"
100 PRINT "bsc = width of sand chamber"
110 PRINT "bgc = width of gravel chamber"
120 PRINT "bfc = width of fibre chamber"
130 PRINT "bwc = width of water cavity"
140 PRINT "hpg = perforated height of gravel chamber"
150 PRINT "hpf = perforated height of fibre chamber"
160 PRINT "hpc = perforated height of water"
170 PRINT "Vs = volume of sand filter"
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180 PRINT "Vg = volume of gravel filter"
190 PRINT "Vf = volume of fibre filter"
200 PRINT "Vwc = total volume of chamber water"
210 PRINT "Ms = mass of sand filter"
220 PRINT "Mg = mass of gravel filter"
230 PRINT "Mf = mass of fibre filter"
240 INPUT "Enter H:", H
250 INPUT "Enter C:", C
260 PRINT "hpg="; H / 3; "cm"
270 PRINT "hpf="; H / 3; "cm"
280 PRINT "hpc="; H / 6; "cm": PRINT: PRINT
290 PRINT "hsc="; H / 2; "cm": LET hsc = H / 2
300 PRINT "hgc="; hsc - C; "cm": LET hgc = hsc - C
310 PRINT "hfc="; hsc - 2 * C; "cm": LET hfc = hsc - 2 * C: PRINT: PRINT
320 PRINT "bsc="; H / 2; "cm": LET bsc = H / 2
330 PRINT "bgc="; H / 3; "cm": LET bgc = H / 3
340 PRINT "bfc="; H / 6; "cm": LET bfc = H / 6
350 PRINT "bwc="; H / 12; "cm": LET bwc = H / 12: PRINT: PRINT
360 PRINT "Vs="; (22 * hsc / 28) * ((bsc - 2 * C) ^ 2 - (bgc) ^ 2); "cm^3"
370 PRINT "Vg="; (22 * hgc / 28) * ((bgc - 2 * C) ^ 2 - (bfc) ^ 2); "cm^3"
380 PRINT "Vf="; (22 * hfc / 28) * ((bfc - 2 * C) ^ 2 - (bwc) ^ 2); "cm^3"
390 LET Vs = (22 * hsc / 28) * ((bsc - 2 * C) ^ 2 - (bgc) ^ 2)
400 LET Vg = (22 * hgc / 28) * ((bgc - 2 * C) ^ 2 - (bfc) ^ 2)
410 LET Vf = (22 * hfc / 28) * ((bfc - 2 * C) ^ 2 - (bwc) ^ 2)
420 PRINT "Vwc="; (H * 22 / 28) * (bsc - 8 * C) ^ 2 - (Vs + Vg + Vf); "cm^3": PRINT:
PRINT
430 PRINT "Ms="; 1.52 * Vs; "g"
440 PRINT "Mg="; 1.68 * Vg; "g"
450 PRINT "Ms="; 1.34 * Vf; "g": PRINT: PRINT
460 PRINT "YOU ARE ALWAYS WELCOME, WE ARE DELIGHTED TO RENDER
OUR SERVICE"
470 PRINT "BE ASSURED OF THE BEST WELL MODEL CONSTRUCTION
SPECIFICATIONS"
480 INPUT "DO YOU NEED ANY FURTHER HELP (Y/N)", ANS$
490 IF ANS$ = "Y" THEN GOTO 240 ELSE GOTO 500: PRINT: PRINT
500 PRINT "THANKS FOR CONTACTING US"
510 END
```

RESULTS AND DISCUSSION

The input and output at various level of H (Height of the well model) and C (Thickness of the chamber) are shown in Plate 1 to 5. It was discovered that the quantity of filters (volume and mass) for a well model construction decreases as the thickness of the wall increases at a specified height of well.

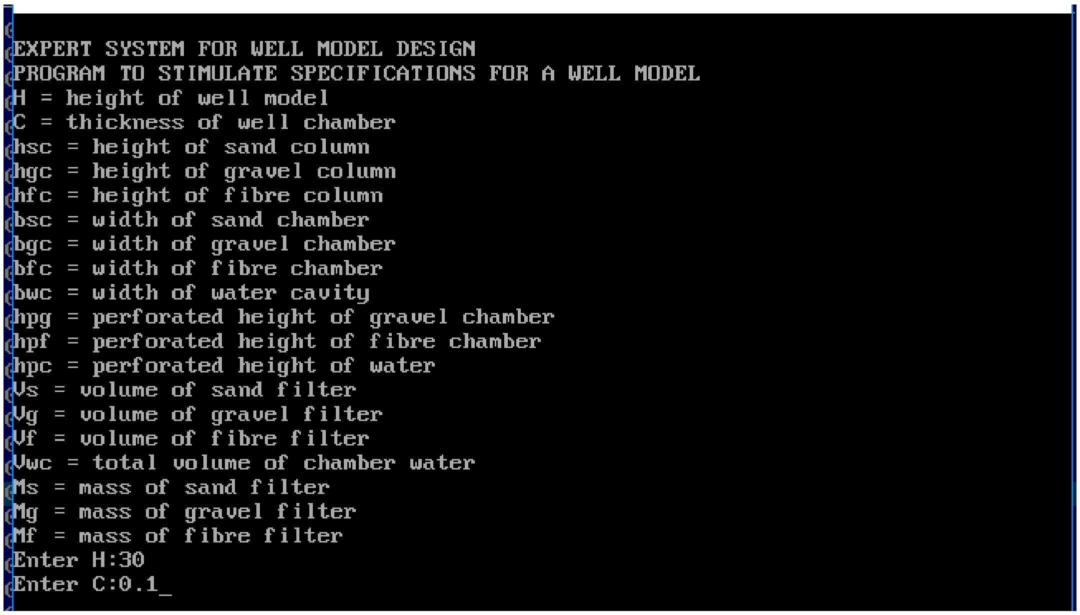


Plate 1: Input from the Expert Program Design @ H= 30 cm; C=0.1 cm

Plate 2: Output from the Expert Program Design @ H= 30 cm; C=0.1 cm

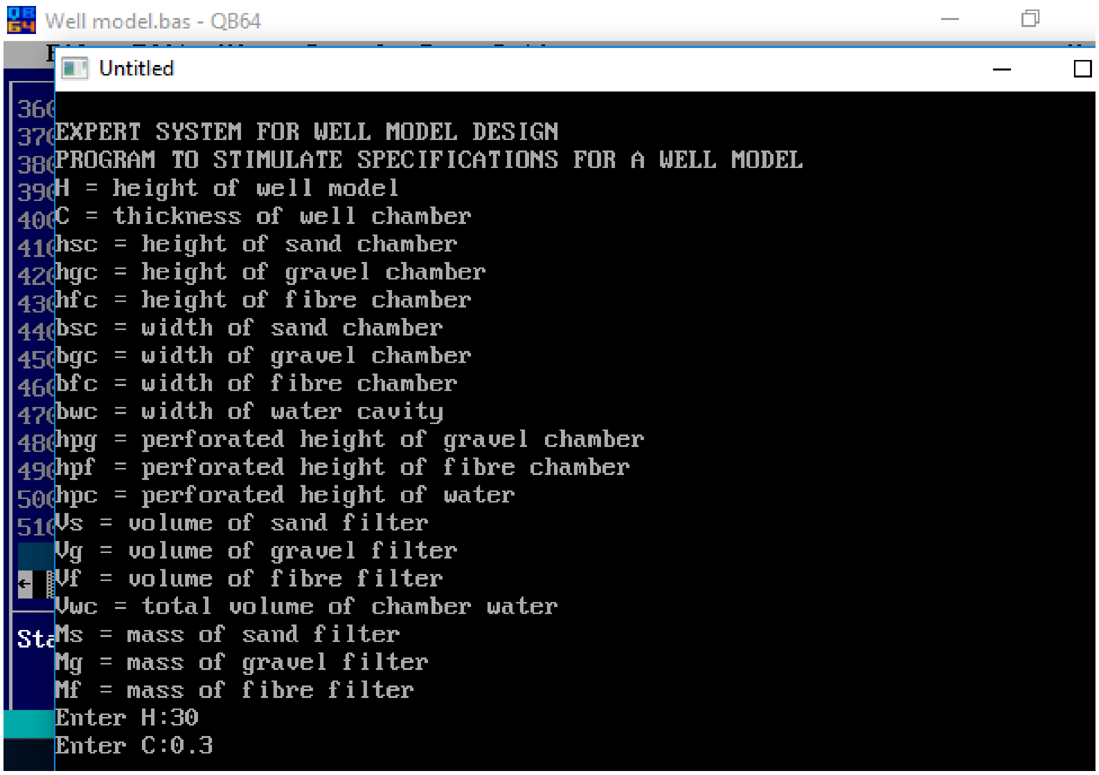


Plate 3: Input from the Expert Program Design @ H= 30 cm; C=0.3 cm

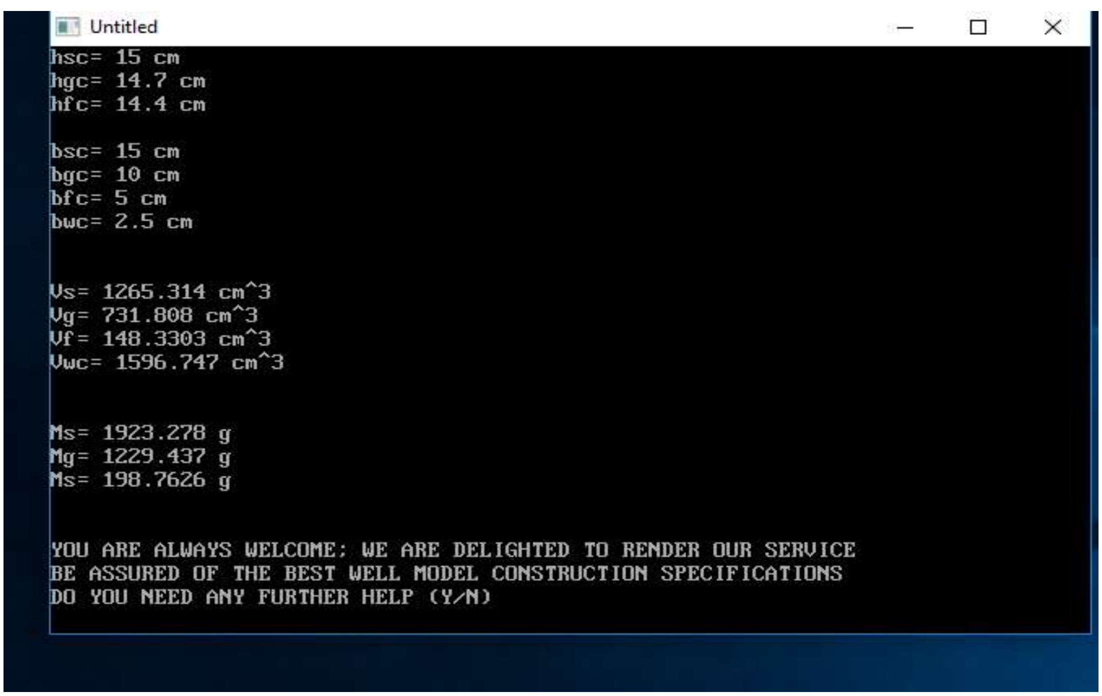


Plate 4: Output from the Expert Program Design @ H= 30 cm; C=0.3 cm

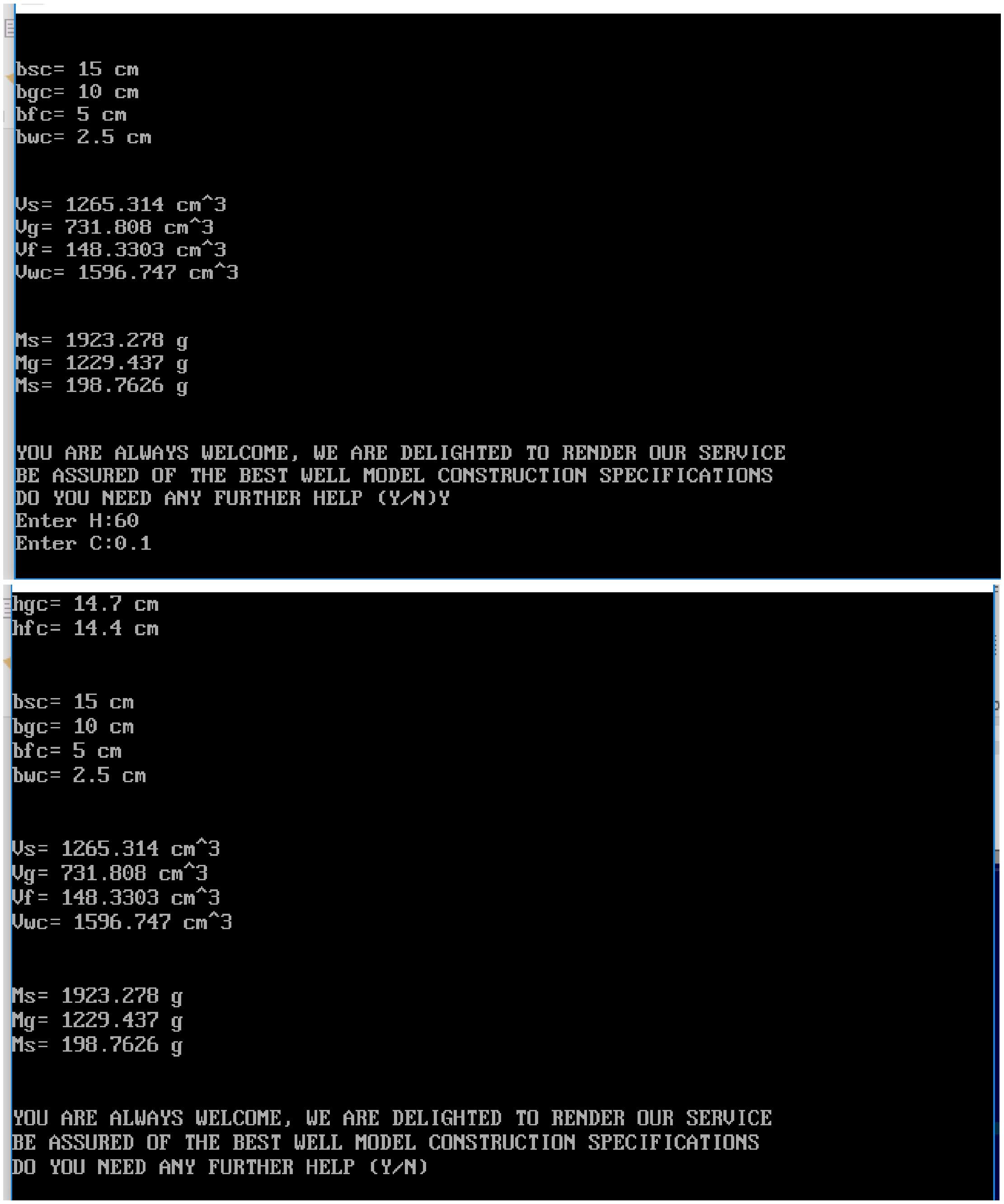


Plate 5: Output Interface @ H= 60 cm and C = 0.1 cm

RESULTS VALIDATION

Validation of results was done by further testing the model programming expert at specified thickness of 1 mm, 2 mm and 3 mm at higher height of well model of

1300 mm, 1400 mm and 150 mm. The resulted value generated was given in Table 1.

The model output specifications were randomly picked and at various thickness and specification height from the design programming. The specifications at different heights of well at constant thickness were correlated with one another (Figure 1-3). From the graphs R^2 was found to be 1. This shows that the specification outputs were precise and reliable since it is perfectly fitted with the generated result of higher height inputs in the programming expert for the formulated parameters.

Table 1: Result Validation

H (cm)	130	130	130	140	140	140	150	150	150
C (cm)	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3
hsc	65.0	65.0	65.0	70.0	70.0	70.0	75.0	75.0	75.0
hgc (cm)	64.9	64.8	64.7	69.9	69.8	69.7	74.9	74.8	74.7
hfc (cm)	64.8	64.6	64.4	69.8	69.6	69.4	74.8	74.6	74.4
bsc (cm)	65.0	65.0	65.0	70.0	70.0	70.0	75.0	75.0	75.0
bgc (cm)	43.3	43.3	43.3	46.7	46.7	46.7	50.0	50.0	50.0
bfc (cm)	21.7	21.7	21.7	23.3	23.3	23.3	25.0	25.0	25.0
bwc (cm)	10.8	10.8	10.8	11.7	11.7	11.7	12.5	12.5	12.5
hpg (cm)	43.3	43.3	43.3	46.7	46.7	46.7	50.0	50.0	50.0
hpf (cm)	43.3	43.3	43.3	46.7	46.7	46.7	50.0	50.0	50.0
hpc (cm)	21.7	21.7	21.7	23.3	23.3	23.3	25.0	25.0	25.0
Vs (cm)3	118550	117228	115911	148184	146651	145122	182386	180626	178869

Vg (cm)3	70933	69947	68968	88682	87538	86401	109169	107855	106549
Vf (cm)3	17487	16999	16518	21884	21318	20759	26964	26313	25669
Vwc (cm)3	214026	206394	198876	267999	259135	250392	330360	320169	310110
Ms (g)	180196	178187	176184	225240	222910	220585	277227	274551	271882
Mg (g)	119168	117512	115867	148986	147064	145154	183404	181196	179002
Mf (g)	23432	22779	22134	29325	28566	27817	36131	35259	34397

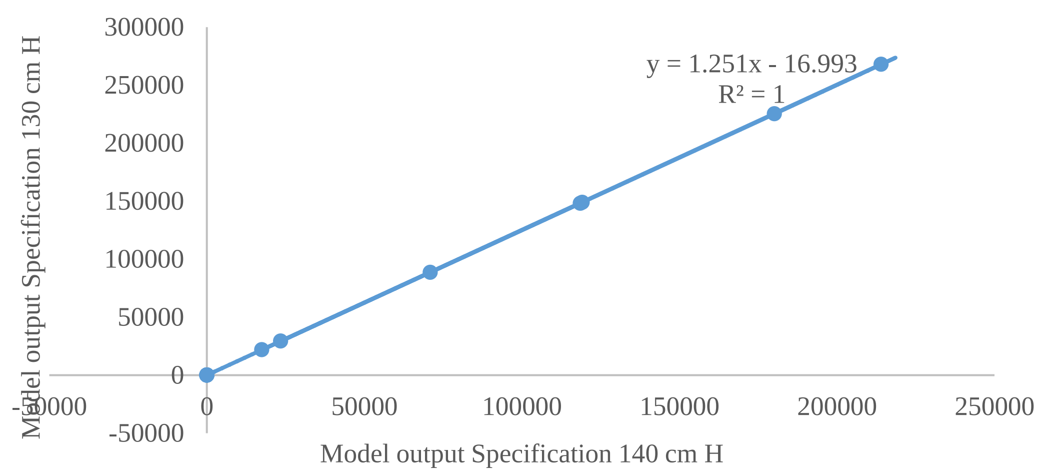


Figure 1: Specification Validation @ 1 mm

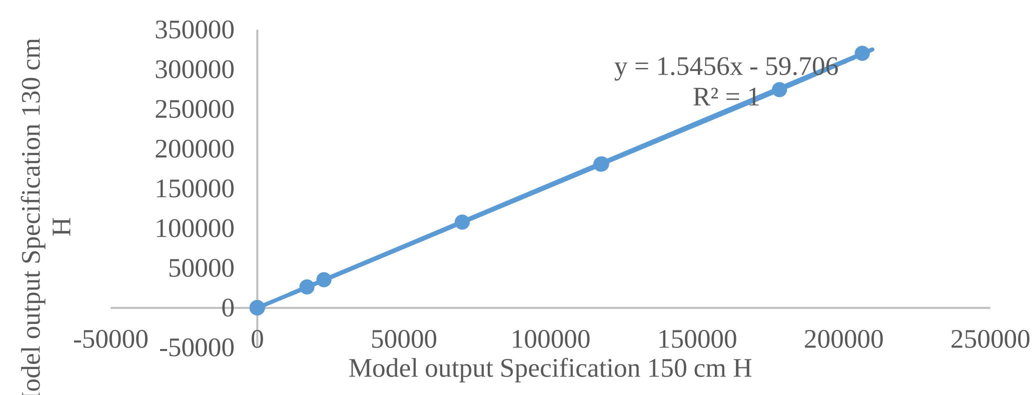
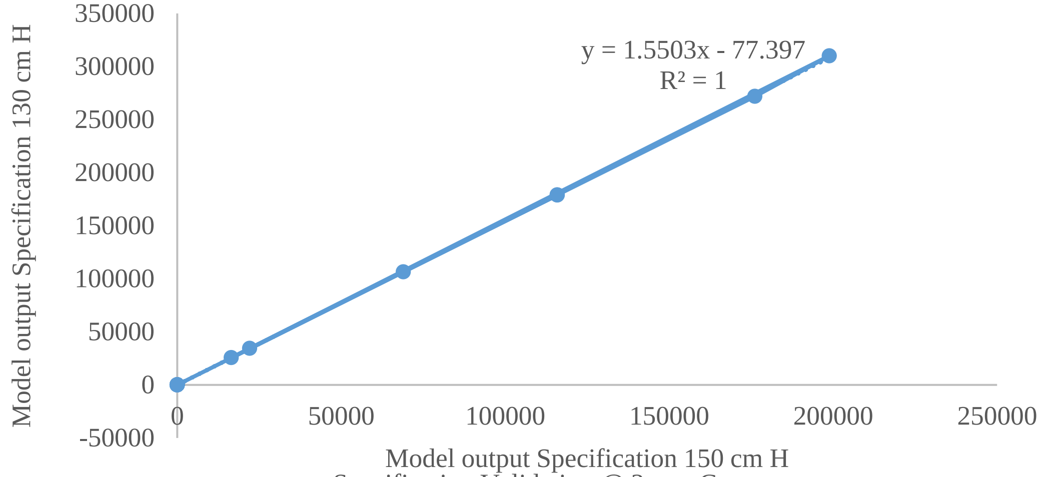


Figure 2: Specification Validation @ 2 mm



Specification Validation @ 3 mm C

Conclusion and Recommendations

The expert system was designed in such a way that it can provide specifications for different sizes of well model based on height and thickness. The software streamlined design rules for generating all specifications to two factors dependent (height of well, and its thickness). The expert system is capable of problem solving such as design activities including evaluation, modeling and decision- making process which in turn helps in quantifying material selection for model construction and beyond. The system is a proof of an alternative solution, methodologies and theory generation in the world of artificial intelligent in well model specification design and development. Further research should be carried out by employing the designed expert system in traditional dug well construction as an alternative potable water source for rural community. Evaluation of water quality analysis arising from well construction using the design expert system is recommended.

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