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Design of Concrete Mixes by Systematic Steps and ANN

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ABSTRACT

The current research caters for the possibility of arriving at a system for designing concrete mixes easily using available materials locally by specified wide ranges of pre-requisites of three main prescribed properties to cover a good variety of practical mixes, which are water, water-cement ratio and total aggregate-cement ratio. Using these three properties, a tri-linear form was constructed by graphical technique manner based on absolute volume approach. This approach defines as a summation of absolute volume for each of these three materials individually water, cement and aggregate should be equal to the absolute volume of whole concrete mixture based on these altogether. A quad-form area which includes a wide range of mixes can be formed from this representation. This area should achieve all the prescribed properties aforementioned. Artificial neural network concept used in this study also to build easily and quickly system which can be translated into Excel sheet. This system predict proportions of concrete mixture and the compressive strength using the results designed by the quad-form area method in addition to the data from literature around 500 mixes based on local materials used in Iraq. Six input parameters (water to cement ratio, the slump, % of fine to total aggregate content, maximum aggregate size, fineness modulus of fine aggregate and the compressive strength) were used in this system to get the outputs. In addition, nine input parameters ((water, cement, sand and gravel contents) and the properties of the mix (Fineness modulus, W/C ratio, the slump, % of fine to total aggregate and the M.A.S)) were used as basis of compressive strength model. The algorithm of this system aimed to reduce the high number of trail mixes error as well as saving the labors, cost and time. Results indicated that the concrete mix design and the compressive strength model can be predicted accurately by using graphical perspective and the ANN approach.

Key words: **Concrete, Compressive strength model, Artificial Neural Network, Quick method, Quad-form area method, Graphical solution.**

1. Introduction

Borehole sealing is important issue for different purposes from environmental and healthy point of view such as deep holes of abandoned oil and gas fields as well as holes used for injection Carbone dioxide. In addition, it can include those used for site investigations for location of radioactive repositories and for disposal high level waste (HLW) for long periods. One of the main materials usually used for sealing and grouting in deep borehole are concrete. The ideal concrete recipe means good properties regarding fresh and hardened states.

Concrete in simple words is a mixture consists of two main parts (paste and aggregate). The paste in turn, consists of cement (binder material) and water. The paste plays important role as lubricant between the particles and binding them by filling all voids and thus converting the system into a rigid mass. This conversion takes place under chemical reaction between cement and water (Seung, 2003).

The process of determining the quantities of concrete ingredients are mixture proportioning, to achieve the specified characteristics of the concrete. A suitable proportioned concrete mix should possess these quantities (Yousif et al, 2010), acceptable workability, durability, strength, and the uniform appearance of the hardened concrete and finally the economy. The engineer must determine the proportion of the input materials to achieve these characteristics.

Consideration of the basic principle of mix design is significant for the actual calculation used to establish mix proportions. Only with suitable selection of materials and mixture characteristics we can achieve the above quality to be obtained in the concrete construction. Mixture of a certain characteristics can be selected based on the intended use of the concrete, for that reason the concrete mixture can be proportioned in advance. These characteristics include the exposure condition; the building elements shape, and the physical properties of the concrete required for that particular structure (Yousif et al, 2010).

Strength of concrete is an important issue assumed by designers when determining structural dimensions. The concrete properly proportioned, mixed, placed and cured are must be compatible with the properties specified by the designer. Proportioning of concrete will define its properties in both fresh and hardened states. The designer is concerned with important issues during the plastic state, including the modulus of elasticity, strength, durability as well as the porosity of the concrete.

Other factors an influence the properties of concrete on the site. These are transportation problems, delay casting and some weather conditions. To avoid these problems, minor adjustments in the mix proportions are required.

Artificial neural network (ANN) is not restricted to a specific equation form; however, it requires sufficient input–output data. Using ANN the new data can retrained continuously, so that it can suitably adapt with new conditions (Seung, 2003).

Concrete mix design undergoes the same category of problems. Additionally, concrete development requires large sets of trial, and this itself is a very complex problem. ANN can establish a relationship between input and output data, so this feature can be used to obtain some sort of various design concrete parameters of both normal as well as high performance. From this point, the use of ANN may reduce the requirement of a large number of trials in concrete mix development.

In this study, to develop ANN models for concrete mix design and compressive strength sufficient set of mix proportions with corresponding characteristic (strength, water contained; cement contained; coarse aggregate contained; fine aggregate contained; maximum aggregate size; slump test data and fineness modulus of aggregate) are required (Rishi, 2003).Published data (about 500 sets) by (Othman, 1986, Yousif, 1987, Al-Alou, 1989, Kashmola, 1999, Al Jader, 2007) were used.

2. Scope and objective

Extensive publications had investigated mix design topics. Some of these studied had taken some sort of complicated way, and others developed for special cases. These factors made some difficulties to apply their experience directly using local materials utilized in Iraq. Hence, developing a method for estimating concrete mixture proportions using these materials is required to make it easy, available and up to date for construction manufacturing.

The objectives of this study are as follow:

a. Propose an easy and systematic way depending on the correlations between wide practical ranges of (W/C ratio), (A/C ratio) and water content. This gives optimum mix proportions using local, available materials by the proposed method.
b. Discuss the development of the ANN for the design of optimum concrete mixture and prediction system of compressive strength based on local materials, and then translate these two systems as user-friendly (Excel sheet).This is an effective tool to minimize the errors that are avoidable through the investigations of mix proportioning as well as providing information of the strength to facilitate the removal of the form and construction scheduling.

3. General methods of designing concrete mixes

Extensive studies in the literature on concrete mix design methods and currently used in different parts of the world. In contrast, few literature studies are available dealing with designing mixes using analytical techniques. These methods depend on empirical relations developed from wide investigations. The process of selecting proportions of mixture is different among various methods. These can be generally summarized as follow:

3.1 The British (D.O.E) method

This method is a practical and suitable method for designing concrete which is published by the Department of Environment (D.O.E) of United Kingdom. It had been used following ranges:

Two types of aggregate (uncrushed and crushed), extensive cement types (O.P.C, R.H.P.C and S.R.P.C), and wide ranges of aggregate specific gravity and finally, large ranges of W/C ratio (0.3-0.9), free water demand (100-260 kg/m^3) and compressive strength for cube's specimen (Teychenne et al, 1975).

3.2 The American concrete Institute (ACI) method

Practical method for designing concrete, ACI method can design normal concrete with entraining air as well as take into account requirements of durability. In the same way, this method has a wide range of free water demand (125-250 kg/m^3), water to cement ratio (0.35-0.8) and finally wide ranges of the cylinder compressive strength at 28 days (14-41 MPa)

(Raju, 1981).

3.3 Murdock method

Surface Index is a new concept proposed by Murdock. It gives an important role for coarse aggregates as well as fine aggregates. It divides the total aggregates designed by this method by the fine and coarse aggregates (Raju, 1981).

3.4 The UNESCO (G/S) method

This method used as a practical and approximate way to investigate concrete proportions. Selection of aggregates mix proportions depends on the properties of the project; strength requirements as well as the properties of available aggregates. Maximum size of coarse aggregates plays a main role to define the amount of cement. Generally, it ranges from (gravel/sand) between (1.5:2.4) and the high value of (G/S) gives high-strength (UNESCO, 1971).

4. Background of the proposed method

The term which is known as the “absolute volume” for any component or mixture represents the summation of the individual ingredient absolute volume within that component or mixture. From this perspective, it can represent the concrete in the trilateral form as triangle (Fig. 1)(Al Jader, 2007, Zakaria and Mohammed, 2011). This form represents three main concrete components which are cement, water and total aggregates (coarse and fine).

This figure represents 1 m^3 of compacted concrete consisting of water, cement and total aggregates. Corner C represents cement mixture with 1 m^3 volume without water and aggregates, and similarly the corners W (water) and A (total aggregates). Any point within this shape border will represent 1 m^3 of mixture consist of proportions of aggregate, water and cement (e.g. point L). This point represents (0.3 m^3) water, (0.4 m^3) cement and finally (0.3 m^3) aggregates in absolute volumes, but not all points located inside this trilateral form will give good or suitable choices for concrete mixture proportions aimed to be used.

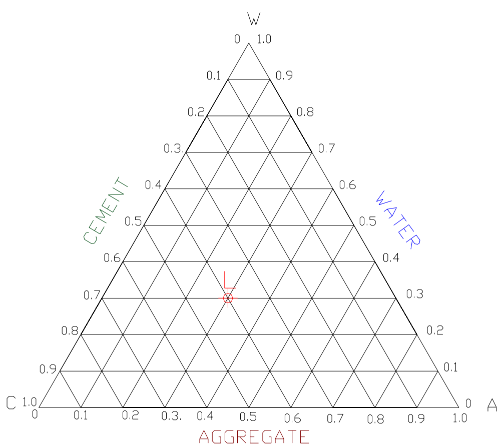

Fig.1.Concrete mixture represents 1 m^3(Al Jader, 2007).

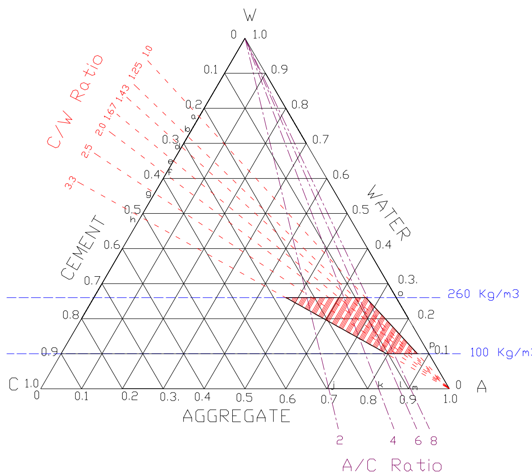

Fig. 2.Principles of Quad-form area method (Al Jader, 2007).

Free water content, water-cement ratio and aggregate-cement ratio had been used to give a suitable suggestion for the mix ingredients proportions are located inside quad-form area Fig. 2.This area had been denoted by the intersection of three lines sets. The first set of lines starts from point A toward (CW rib) representing ranges of cement-water ratios (1.1: 3.3); it had taken as (C/W) instead of (W/C); because the former is a linear relation while the latter is none linear relation. In the same way, the second set of lines starts from W head point toward the base of the triangle (CA base) representing the limits of weight ratios of total aggregates to cement (2: 8).The final set of lines (two) was drawn parallel to the horizontal lines, which represent the limits of free water content ranging of (100 to 260 kg/m^3). All limits had been taken are believed to represent practical and adopted ranges (Simon et al, 1999, Marcia et al, 1997).

After getting quad-form area (red area)(Fig. 2) (Zakaria and Mohammed, 2011)it can be redrawn in a large scale. This will help in defining the properties of this area such as the weight values (kg/m^3) based on the relation between absolute volume and specific weight for each mixture component which are free water content, cement content and total aggregate.This will give the possibility of havinga high number of concrete mixes Fig. 3.

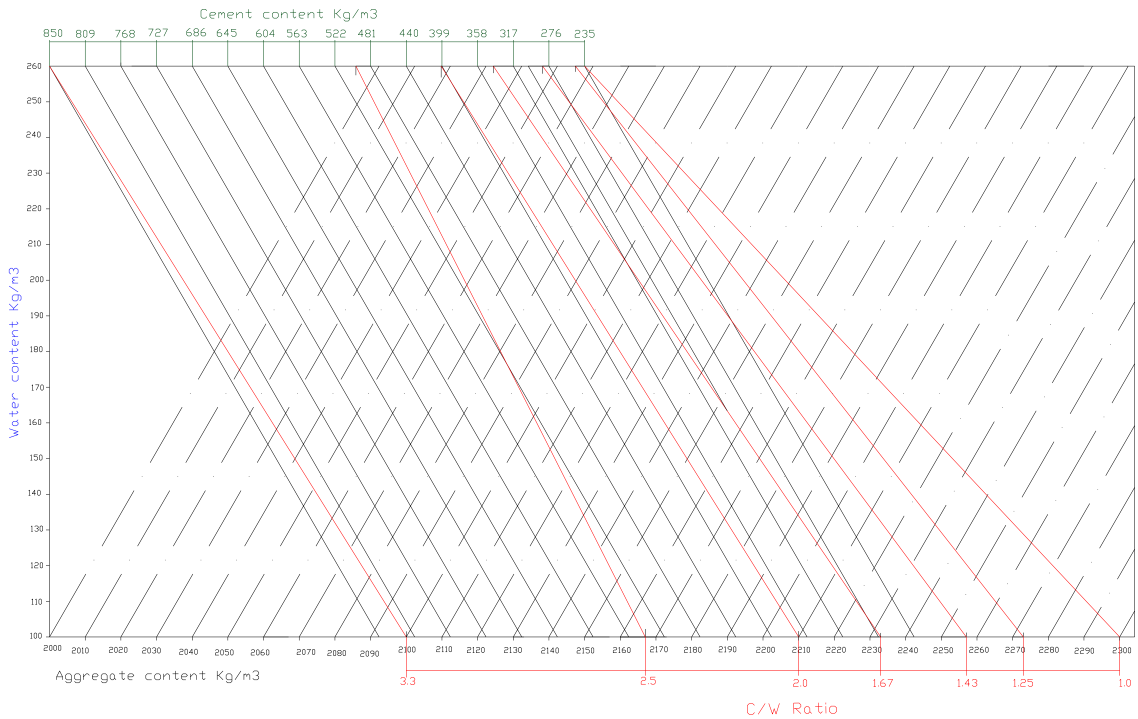

Fig. 3.Quad-formarea, large scale(Al Jader, 2007).

From this area, Fig. 3 had been designed for seven main concrete mixes representing different practical ranges of cement, water contents and total aggregates (fine and coarse) which will be investigated experimentally as shown in table 1.

Table 1: Mixture proportions of concrete (kg/m^3)

Concrete mixes	Cement content	Water content	Total aggregate	W/C ratio by wt.	A/C ratio by wt.
Mix A	250	210	1900	0.84	7.6
Mix B	265	186	1908	0.70	7.2
Mix C	285	128	1978	0.45	6.9
Mix D	300	163	1939	0.54	6.5
Mix E	315	189	1957	0.60	6.2
Mix F	387	198	1882	0.51	4.9
Mix G	496	173	1885	0.35	3.8

5. Experimental program

5.1 Materials

Ordinary Portland cement (OPC) of Green Iraqi brand complying with Iraqi standard regulations (IQS, No. 5, 1984) was used throughout the investigation.Table 2gives the chemical composition and the physical properties of the cement.

Table 2: Properties and compositions of cement Portland used in the study

Chemical composition (% by wt.)									
Cement oxides						Main cement components			
Al_2O_3	SiO_2	Fe_2O_3	CaO	SO_3	MgO	C_3S	C_2S	C_3A	C_4AF
6.24	21.39	2.64	62.06	2.05	2.7	38.46	37.70	12.07	8.02
Ranges of Iraqi standard regulations(IQS, 1984)									
3-8	17-25	0.5-0.6	60-67	≤ 2.8	≤ 5.0	31.3-41.05	28.61-37.9	11.96-12.30	7.72-8.02
Physical properties (% by wt.)									
Fineness (retained on sieve 170)				Setting time (min.)		Compressive strength (MPa)			
8				(Initial) 120	(Final) 360	(3 days) 23.6		(7 days) 32.5	
Ranges of Iraqi standard regulations(IQS, 1984)									
≤ 10				≥ 45 (min.)	≤ 600 (min.)	≥ 16		≥ 24	

The coarse and fine aggregates used were naturalriver aggregates complying with (BS 882: 1992). Three fractions size of fine aggregates were used (coarse, middle and fine). Fig.4a shows the sieve analysis for these fractions and the properties for these fractions are given in table3.Two types of coarse aggregateswere used depending on the maximum aggregate size (20 mm and 12.7 mm).Sieve analysis of these fractions,and the properties are given in Fig.4b and table 4 respectively.

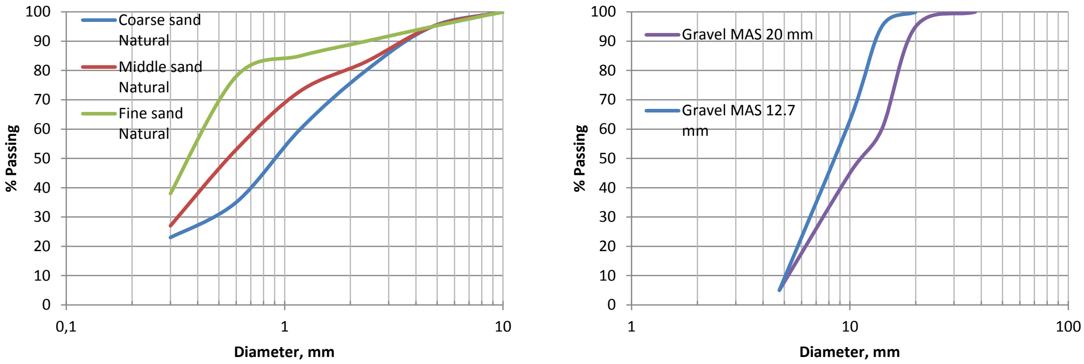

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Fig.4. Sieve analysis, a) Fine aggregate, b) Coarse aggregate

Table 3: Properties of fine aggregate

Type of sand	Specific gravity		Absorption %	Fineness modulus
	S.S.D	Oven dry		
Coarse sand	2.63	2.56	2.47	3.07
Middle sand	2.61	2.54	2.50	2.69
Fine sand	2.60	2.52	2.54	2.14

Table 4: Properties of coarse aggregate

Type of sand	Specific gravity		Absorption %	Max aggregate size (mm)
	S.S.D	Oven dry		
Gravel type 1	2.66	2.62	1.000	12.7
Gravel type 2	2.66	2.62	0.807	20.0

5.2 Variables and mix proportions

Seven different mixes were prepared with the cement content ranges (250-496 kg/m^3), water content (128-210 kg/m^3) and total aggregates (1882-1978 kg/m^3). They were selected from the area quad-formof Fig. 3. Water to cement ratio(0.35-0.84) were selected for preparing concrete specimens as well as seven different ratios of aggregate to cement ratio. The specimens were tested at 7 and 28 days. The mixture proportions of concrete are shown in table 5 for mix A and so on for all mixes.

Table 5: Mixture proportions of concrete – Mix A

Mix A – All aggregate in S.S.D state W/C = 0.84, Cement content = 250 kg/m^3, Water content = 210 kg/m^3 and Total aggregate = 1900 kg/m^3			
M.A.S (mm)	Sand grading	Sand (kg/m^3)	Gravel (kg/m^3)
20	Coarse	739	1161
12.7	Coarse	855	1045
20	Medium	712	1188
12.7	Medium	821	1079
20	Fine	691	1209
12.7	Fine	794	1106

Then, mixes had been prepared in accordance with the mixture proportions. Table 6 shows the numbers of specimens that were conducted. From this table, the number of specimens for each mix was 36 specimens while the overall number was 252 cubs.

Table 6: Mixture proportions of concrete (kg/m^3)

Concrete mix	Fine aggregate	MAS of Coarse aggregate (mm)	Type of test		Age of specimen	Number of specimen
Mix A	Fine sand	12.7	Slump for each mix	Compressive strength	7 and 28 days	6
		20			7 and 28 days	6
	Middle sand	12.7			7 and 28 days	6
		20			7 and 28 days	6
	Coarse sand	12.7			7 and 28 days	6
		20			7 and 28 days	6

5.3 Test methods

5.3.1 Compression test

Compressive strength test was conducted based on (BS 1881: 1983) at 7, 28 days. The sizes of the cubes specimens were (100 mm x 100 mm x 100 mm), and each series of test had three specimens.

5.3.2 Workability

To indicate a concrete consistency,slump cone test was tested based on (BS 1881: 1983).

6. Artificial neural network system

6.1 Neural networks

The neural network is a powerful toolthat candeal with nonlinear functions.The input data were within the training range and the output dataobtained were also within the training set which is a good indicator of the power of the training network(Yousif et al, 2010). To solve problems using ANN approachrequires the preparation of data as aprerequisite. This procedure is crucial to the success of applying ANN approach.

Neural networks performance largely depends on the input data set that was trained especially when using the back propagation network. A multilayered feed-forward neural networkwas adoptedin this research with a back-propagation algorithm. MATLAB software package was used to develop the ANN(Yousif et al, 2010). Training the ANN modelsrequires dividing the entire experimental data into two sets, training and testing data.Around445, patterns were used to train the different network architectures, and the remaining 50 patterns were used for testing the verification of the prediction ability of each trained ANN model.Theconstruction of the ANN model depends on usingthe techniques referred toas

"Levenberg-Marquardt (LM)"which is built in MATLAB and proved to be efficient training functions (Yousif et al, 2010).

6.2 Data based in this study

Applicationof neural networks to find optimum concrete mix proportioning and compressive strength modelwas based on the experimental data of the concrete mix that was carried out by local materials in most Iraqi areas only.This includes the results estimated by the methodsuggested in this study andthe published data(Othman, 1986, Yousif, 1987, Al-Alou, 1989, Kashmola, 1999, Al Jader, 2007).Around 500, concrete mixes made by local materials which include ordinary Portland cement produced by cement factories,BADOSH and SINJAR complying with Iraqi specification (IQS, No.5, 1984) were used. For aggregates, river sand in accordance with (BS 882: 1992)available atKanhash and Khazer; androunded gravel from riversas coarse aggregate were used. Table 7 shows the range of maximum and minimum values of the parameters that were used representing all concrete mix design which are believed to give the optimum mix proportions using local materials.

Table 7: Ranges of data used

Parameters	Range
Fineness modulus	2.10-3.07
Maximum aggregate size (mm)	12.70 - 40.00
Fine aggregate content %	25.00 - 62.90
Slump (mm)	0.00 - 205.00
Water to cement ratio %	35.00 - 84.00
Water content (kg/m^3)	103 - 264
Cement content (kg/m^3)	193- 496
Sand content (kg/m^3)	441 - 1160
Gravel content (kg/m^3)	685 - 1504
Compressive strength (MPa)	8.00 - 63.00

6.3 Quick method to design concrete

The application of ANN to propose aquick method to design concrete is proposed in this research.This method had been translated into the Excel sheet to make it available and user-friendly to give quicker way based on the reliability of (ANN) tool for modeling the concrete mix proportioning and compressive strength. This model can be useful in reducing the wide number of trail mixes, work in the lab, experimental costs and time. The model has six input parameters, which are the water to cement ratio,the slump, %of fine to total aggregate content, maximum aggregate size, fineness modulus of fine aggregate and the compressive strength. The output parameters from this model are the main concrete ingredients by weight unit (kg/m^3) of mix components (cement content, water content, fine aggregate content and coarse aggregate content).

6.3.1 Advantagesof the method

a. Using a simple and user-friendly program as Excel sheet.This is very easy and available by most of the designersand it does not require high experience to deal with.

b. It is requires input data. The data can be obtained from simple and quick tests at the lab; as well as from the working site.
c. Quicker in giving the amounts of mix proportions and the compressive strength. This is useful in reducing the number of trail mixes, work lab, financial spending and time schedule.

6.3.2 Disadvantages of the method

The input data required for the program must be within the training range. This method is based on local material data to give the optimum results. It should be mentioned however that it can be modified to be implemented on other sets of data by preparing a new Excel sheet with extensive ranges and different types and resources of materials.

7. Results and discussion

7.1 Cement content

Increasing the cement content decreases the water to cement ratio because the amount of water required by this mix to complete the hydration process when all mortar voids are filled and hence it will lead to an increase the compressive strength (Fig.5).

Fig.6 shows the relation between the total aggregate to cement ratio versus cement content. This relationship indicates that the mixes which have minimum aggregate to cement ratio are rich in cement. In contrast high (A/C ratio) leads to the mixes that are poor in cement. However, the minimum limit for aggregate to cement ratio should be defined in the mixture to enveloping aggregate particles in addition to the filling of all the voids between these particles and finally bonding all mixture components with each other and producing a coherent mass (Al-Khalaf and Yousif, 1984, Neville, 2000).

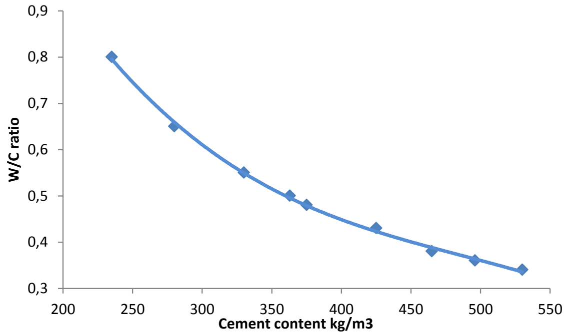

Fig. 5.Water to cement ratio (by wt.) vscement content.

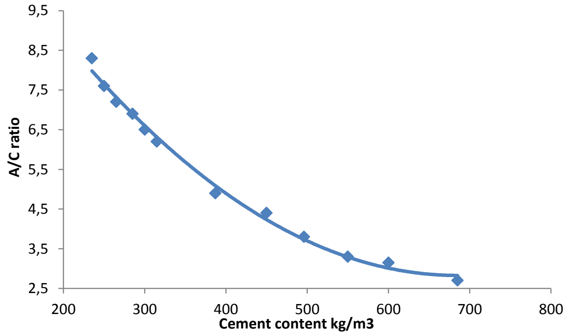

Fig.6. Total aggregate to cement ratio (by wt.) vs cement content.

7.2 Workability

Consistency, viscosity, and mobility are important properties of concrete.They are to be predefined before using the concrete to give an indication about this concrete, where molding fresh concrete quality often related to its workability. Slump cone test is a common and easily way to give the indication of the consistency but it can’t give direct indication about the stickiness and the viscosity of concrete.

Fig.7 shows that the concrete mixes contain high amount of free water which gives flow able concrete, i.e. high slump cone results. Graduation of sand fractions from coarser to finer leads to decreasing slump results. In the same way, M.A.S variance from smaller to larger, gives more flow able concrete also (Fig. 8). This is due to the fact thatcoarser particles requireless water demand than finer particlesbecause they possess relatively smaller surface area (Al-Allou, 1989, Neville, 2000).

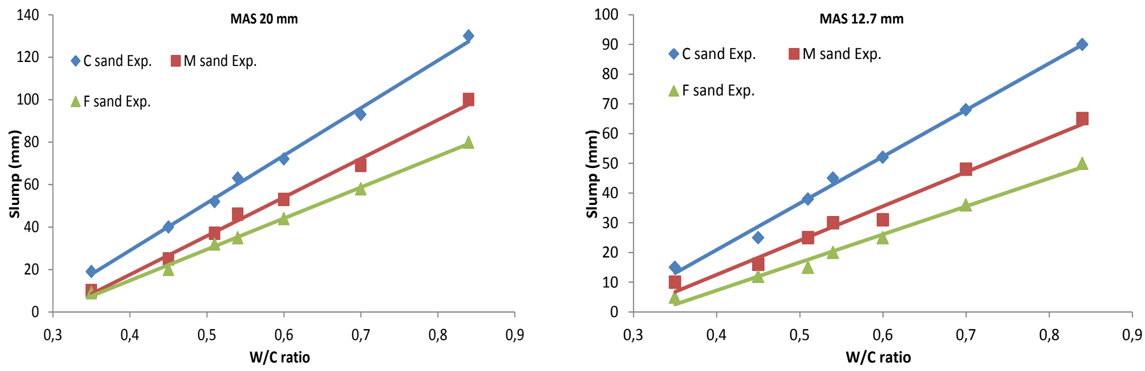

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Fig. 7. Water to cement ratio (by wt.) versus slump results for different gravel MAS and graded sand.

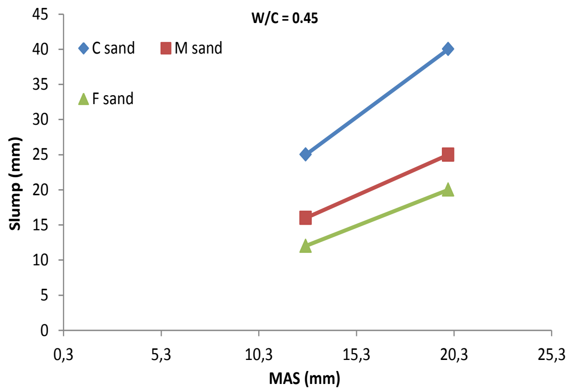

Fig. 8. Effect of MAS on slump cone results for the same water to cement ratio and different sand sizes.

7.3 Compressive strength (Experimental results)

7.3.1 Water cement ratio

Figs. 9 and 10 show one of many factors that affect the compressive strength which is (W/C ratio). When the voids in the concrete being minimum for a good mixture used (dense packing) due to the use of coarse sand fraction compared with middle and fine, the relation between the strength and the water to cement ratio will be inverse in accordance to the Abrams law (Abrams, 1919).

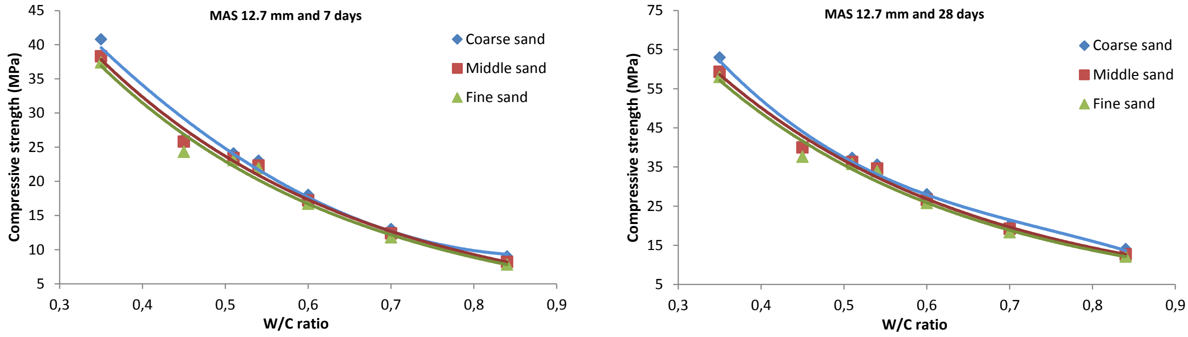

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Fig.9. Water cement ratio (by wt.) vs compressive strength for different age of test and sand fractions gradation, while MAS is 12.7 mm.

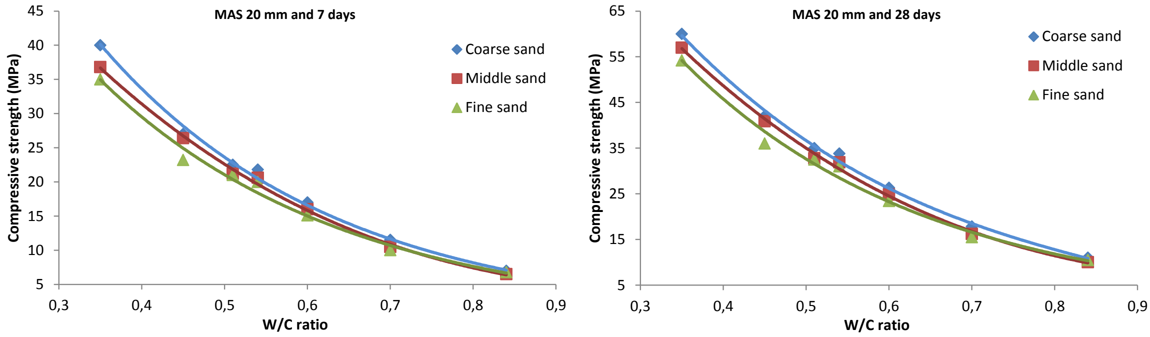

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Fig.10. Water cement ratio (by wt.) vs compressive strength for different age of test and sand fractions gradation while MAS is 20 mm.

7.3.2 Maximum aggregate size

Workability, compressive strength, and shrinkage are affected by maximum aggregate size (M.A.S.) Better workability can be obtained from concrete mixtures with large M.A.S and this is due to decreases in the specific surface. High strength of concrete can be obtained from mixtures having optimal M.A.S of coarse particles (Quiroga and Flowler, 2003). Fig. 11 illustrates that the increasing in the maximum aggregate size leads to the decreasing in the compressive strength with constant water to cement ratio. This can be is explained as the big particles give surface area relatively less for bonding the particles with together, i.e. poor bonding between aggregate and cement paste (Al-Allou, 1989, Al-khalaf and Yousif, 1984, Neville, 2000).

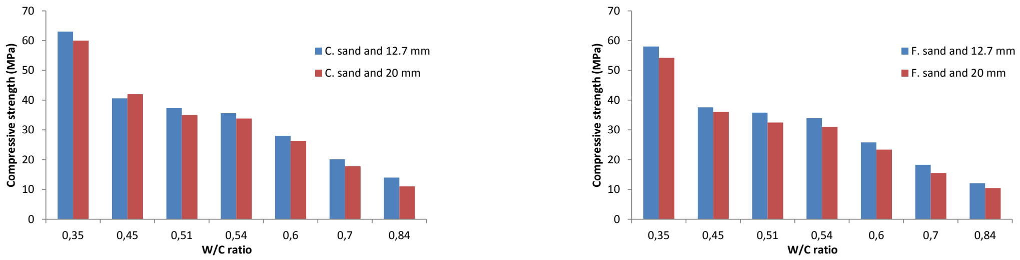

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Fig. 11. Water cement ratio (by wt.) plotted with compressive strength at 28 days, different MAS withthe same sand fractions.

7.3.3 Gradations of fine aggregate

Figs.9 and 10 show that for the same maximum aggregate size and constant water to cement ratio, the coarser sand gave more resistance concrete compared with the other fractions (middle and fine).This is due to the effect of differences in the surface areas in addition to the mix water demands that increases with the decrease of particle size(Al-Allou, 1989).

7.4 Procedure of mix design

The procedure of mix design can be using the following this example for the design of concrete mix with requirements.

7.4.1 Example

Suppose a design concrete mix aiming to be used for casting reinforcement roof concrete is required. The mix should satisfy the following requirements:

- Design compressive strength = 35 MPa at 28 days.
-The coarse aggregatesarerounded river type with M.A.S = 20 mm as well as the fine aggregateswhich are coarse fraction sand, both of them complying with the (BS 882:1992).

To get the properties of such mix, the following steps should be done:

Step 1: Find the water-cement ratio at a compressive strength 35 MPa, coarse sand and 20 mm M.A.S using Fig. 10bit will be to 0.51.

Step 2Determine the cement content which compatible with W/C =0.51usingFig.5 which equal to the 350 kg/m^3.

Step 3: Determinethe total aggregate to cement ratio at 350 kg/m^3 cement content using Fig. 6 that gives (5.5) by.

Step 4: calculate the free water content by multiplying cement content with w/c ratiowhich gives 178.5 kg/m^3.

Step 5: Using the cement content with aggregate to cement ratio the total aggregate content can be found which is 1925 kg/m^3.

Step 6: To split the total aggregatesto the coarse and fine fractions use Murdock method (Al Jader, 2007). The results will be1176 and749 kg/m^{3}for coarse and fine aggregates respectively.

Finally, the properties of the required mix are shown in table 8.

Table 8: Concrete mix designed based on examplerequirements

Material	Cement	Water	Sand	Gravel
Amount kg/m^3	350	178.5	749	1176
Proportions by wt.	1	0.51	2.14	3.36

7.5 Mix design using another procedure

Firstly, steps 1 &2 above are to be repeated. After that, from quad-formarea in Fig.

3,andby using (C/W = 1/0.51 = 1.96) and cement content (350 kg/m^3) the water and total aggregate content will be (175 kg/m^3) and (1917 kg/m^3) respectively.

Finally, calculate fine and coarse aggregate by Murdock method (Al Jader, 2007), and the mix characteristics are shown in table9.

Table 9: Concrete mix designed by quad-form area

Material	Cement	Water	Sand	Gravel
Amount kg/m^3	350	175	749	1176
Proportions by wt.	1	0.50	2.13	3.35

7.6 Quick method to design concrete

ANN method was applied to establish quick and easy way to get an indication about concrete mix proportions.About 500 data sets were used. Some of the data were published (Othman, 1986, Yousif, 1987, Al-Alou, 1989, Kashmola, 1999, Al Jader, 2007) while the remainder was preparedbased on local materials covering most of the regions in Iraq. This method was translated as an Excel sheet. Some of the data(443 patterns) were used to train the different network architectures (Fig. 12) and the remaining 50 patterns were used for testing, to verify the prediction ability of each trained ANN model (Fig. 13).

The method had been designed to take six input parameters (F.M, W/C ratio, the slump, % of fine to total aggregate, M.A.S and the compressive strength). Fig. 14 shows howthe inputdata affects designing concrete process. It can be seen that each input parameter has different effect on the results. The importance of each parameter in descending order starts with the F.M for fine material which had the maximum effect followed by water cement ratio and finally the slump which showed the minimum effect on the output data.

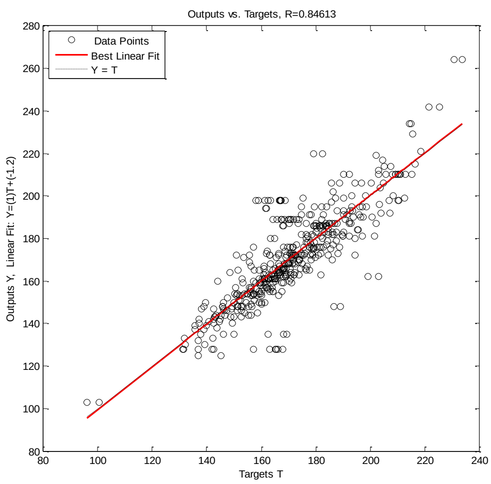

Fig. 12. Experimental trained data and corresponding ANN predictions for concrete mix design.

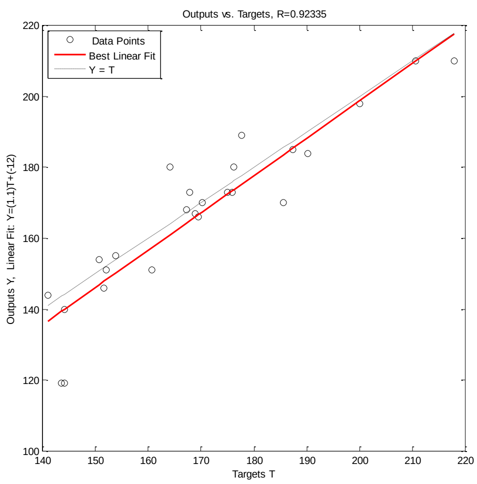

Fig. 13. Experimental tested data and corresponding ANN predictions for concrete mix design.

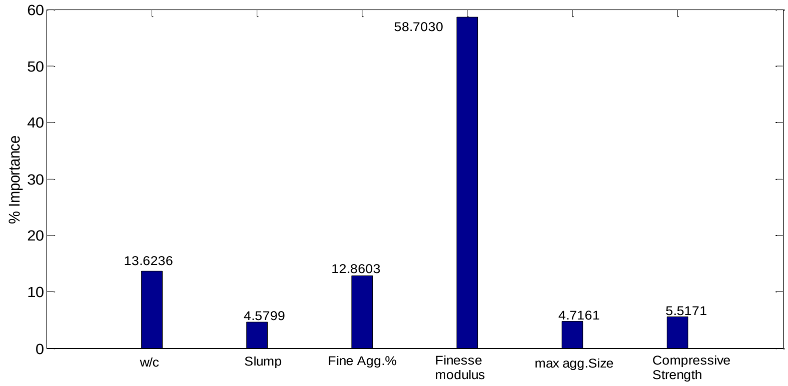

Fig. 14. Influences of mixture components and mix properties required on designing concrete mix.

Four output parameters (weight units of mix components include water, cement, fine aggregate and the coarse aggregate) were obtained(Fig. 15). This figure shows the design results for predefined condition mix properties. Compressive strength will increase with slight increase of water, sand and cement.In contrary, a marked decrease of gravel content is noticed with the increase of compressive strength.

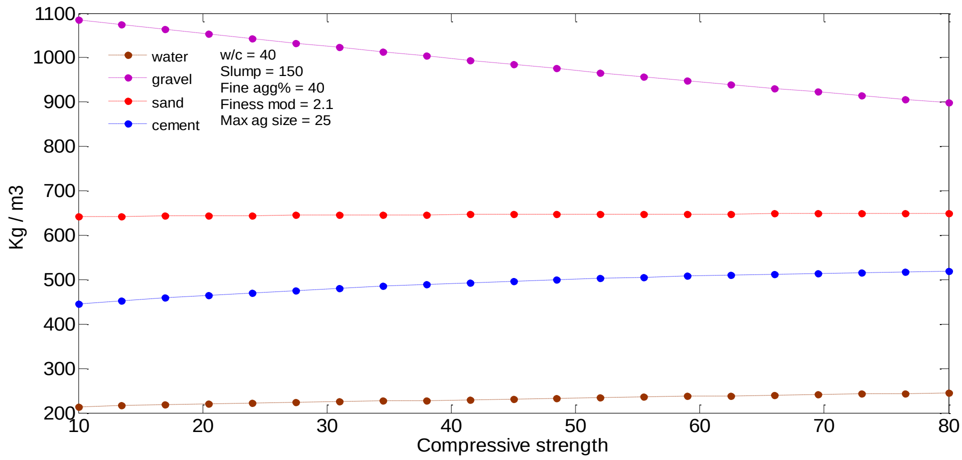

Fig. 15. Behaviors of outputs design components.

7.7 Comparison study (design concrete)

A comparative study was carried out between the suggested (proposed by Quad-form area and quicker by ANN) method and other well-known methods (ACI (Raju, 1981), British (D.O.E) (Teychenne et al, 1975) and G/S (Unesco, 1971)).The comparison results are given in Tables 10& 11.In these tables the numbers of concrete mixes designed using both present proposed methods and the other methods are tabulated. This comparison was based on compressive strength and slump results. The results of the proposed method were very similar to those obtained from the other three methods.

Table 10: Concrete mix designed for slump ranges (30-60 mm) and (20 mm MAS)

Grade of compressive strength (MPa)	Method of design	Cement content (kg/m^3)	Mix proportions by wt.	Slump (mm)	Actual compressive strength (MPa)
30	Quad-form	315	1:2.43:3.82/0.56	63	38.8
	ACI	297	1:2.55:3.55/0.58	52	33.0
	G/S	300	1:2.15:3.88/0.55	47	35.7
	D.O.E	335	1:1.67:3.89/0.54	30 - 60	36.5
	Quick method	305	1:2.43:3.85/0.52	63	37.4
40	Quad-form	375	1:2.00:3.13/0.48	50	43.5
	ACI	365	1:1.97:2.91/0.51	42	40.8
	G/S	350	1:1.78:3.24/0.49	45	41.5
	D.O.E	395	1:1.33:3.24/0.46	30 - 60	46.5
	Quick method	355	1:1.95:3.42/0.50	50	37

Table 11: Concrete mix designed for slump ranges (30-60 mm) and (12.7 mm MAS)

Grade of compressive strength (MPa)	Method of design	Cement content (kg/m^3)	Mix proportions by wt.	Slump (mm)	Actual compressive strength (MPa)
30	Quad-form	320	1:2.70:3.31/0.57	49	39.3
	ACI	323	1:2.00:3.62/0.51	55	36.0
	G/S	320	1:2.18:3.29/0.59	40	37.2
	D.O.E	370	1:1.84:3.00/0.54	30 - 60	36.5
	Quick method	350	1:2.51:3.04/0.55	45	39.0
40	Quad-form	375	1:2.30:2.82/0.48	35	45.0
	ACI	393	1:1.63:2.67/0.51	50	43.0
	G/S	380	1:1.76:2.65/0.50	55	44.3
	D.O.E	435	1:1.42:2.54/0.45	30 - 60	46.5
	Quick method	370	1:2.39:2.87/0.41	38	53.9

7.8 Compressive strength(quicker model)

In the past decades, lots of research carried out to predict concrete compressive strength. However, there is still a space in this field for development. ANN technique was used to establish a quicker model which is user-friendly tool using an Excel sheet, to estimate concrete strength based on data from literature(Othman, 1986, Yousif, 1987, Al-Alou, 1989, Kashmola, 1999, Al Jader, 2007).The correlation coefficient (R^2) of this model was 0.974.The data were divided in two groups. The first was used to train the different network architectures (Fig.16) while the second group was used for testing (Fig. 17).

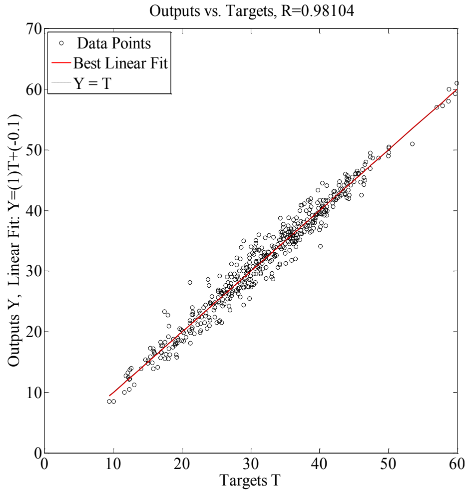

Fig. 16. Experimental trained data and corresponding ANN predictions for compressive strength behavior.

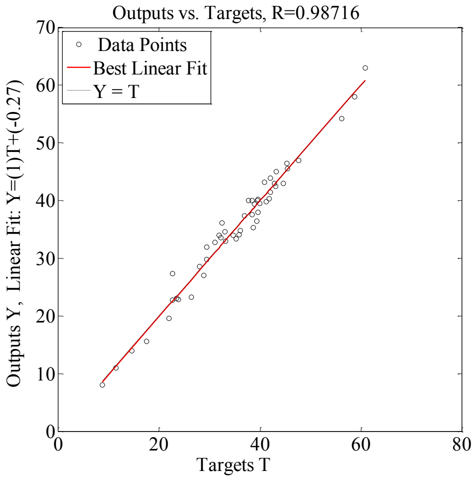

Fig. 17. Experimental tested data and corresponding ANN predictions for compressive strength behavior.

The model had nine input parameters includes concrete ingredients (water, cement, sand and gravel contents) and the properties of the mix (F.M, W/C ratio, the slump, % of fine to total aggregate and the M.A.S)(Fig. 18). In this figure the effects of the input data on the strength of concrete is shown. F.M for fine material had the maximum effect, and the slump had the minimum effect on the strength of concrete.

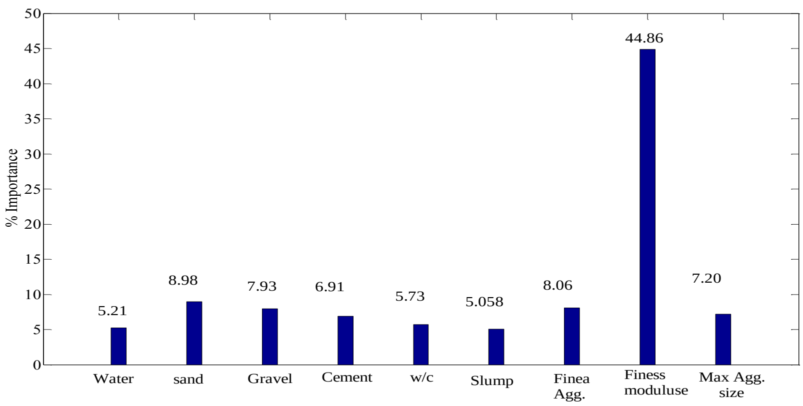

Fig. 18. Influences of mixture proportions and the properties required on compressive strength behavior.

Using the results obtained, the effect of variation of both gravel content and fineness modulus on the strength of concrete were investigated (Fig. 19). This figure shows that the compressive strength will be constant for different values of F.M until the gravel content is about 1100 kg/m^3. Beyond this value,the compressive strength started to decrease, and the effect of F.M became clearer.

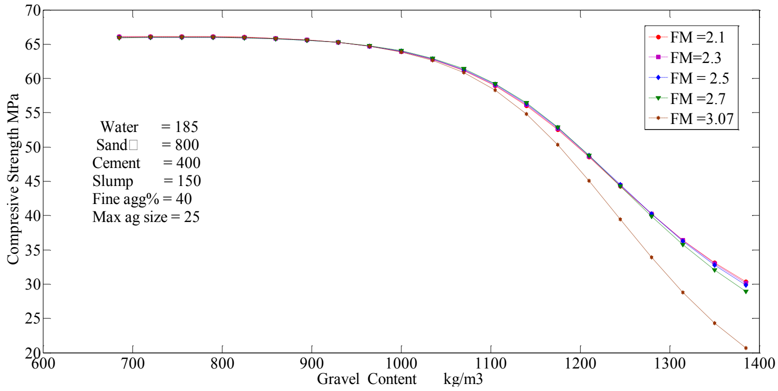

Fig. 19. Behavior of compressive strength under mentioned conditions with variation of fineness modulus and gravel content.

Fig.20 show the all the previous comparisons between compressive strength results that were obtained from theoretical proposed model with the published experimental data (Othman, 1986, Yousif, 1987, Al-Alou, 1989, Kashmola, 1999, Al Jader, 2007). The results reflect good correlation with more than 300 experimental results.

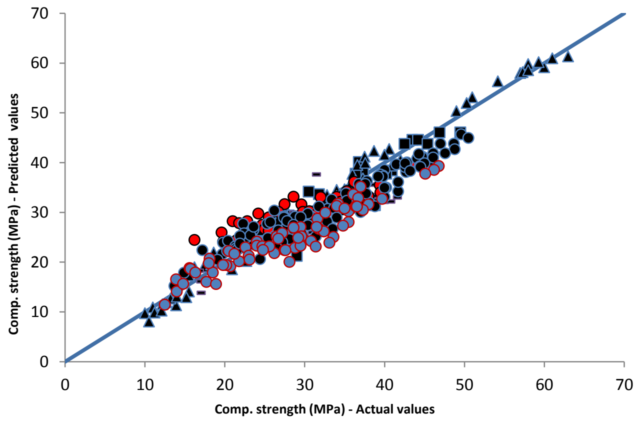

Fig. 20. Experimental compressive strength versus estimated compressive strength.

8. CONCLUSIONS

Two methods had been established to estimate concrete proportions. The first is based on some figures referred to as"Quad-form area method". The second method was quick method used by using Excel sheet established by ANN. Furthermore, compressive strength model depending on nine input parameters using ANN was established.

Quad-form area method is to be formed by three main pre-requisites requirements, which are water content, cement water ratio and total aggregate to cement ratio. In this area extensive numbers of mixes can be obtained which are compatible with practical pre-requests ranges. It is obvious that this method gives total aggregate, and this makes the designer more flexible to select optimum aggregate mixture as dense as possible by defining the M.A.S for coarse aggregate and also the gradation of fine aggregate. Workability based on the slump, decreases for the constant water-cement ratio with the gradation of sand from coarser to finer. In contrast, it will increase with graded gravel, from smaller M.A.S to larger due to decrease of surface area. It has been demonstrated that the ANN technique is reliable for predicting a quick system to design concrete proportions and estimate its compressive strength.

So this approach was capable of finding relationship between different uncertain parameters with multiple inputs and output principles. It was found that the characteristics of this system were reducing the large number of trail mixes and this leads to decrease of labor, financial expenditure and finally gives a flexible schedule for the work construction activities on site. It can also provide essential imprecision in the design steps proposed by other methods. This way offers flexibility to decide the appropriate value for unclear parameters by mix design and does not require high quality professional for its application. Comparative studies with common methods showed that the Quad-form area and Quick methods were giving very well accepted results based on local materials.

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