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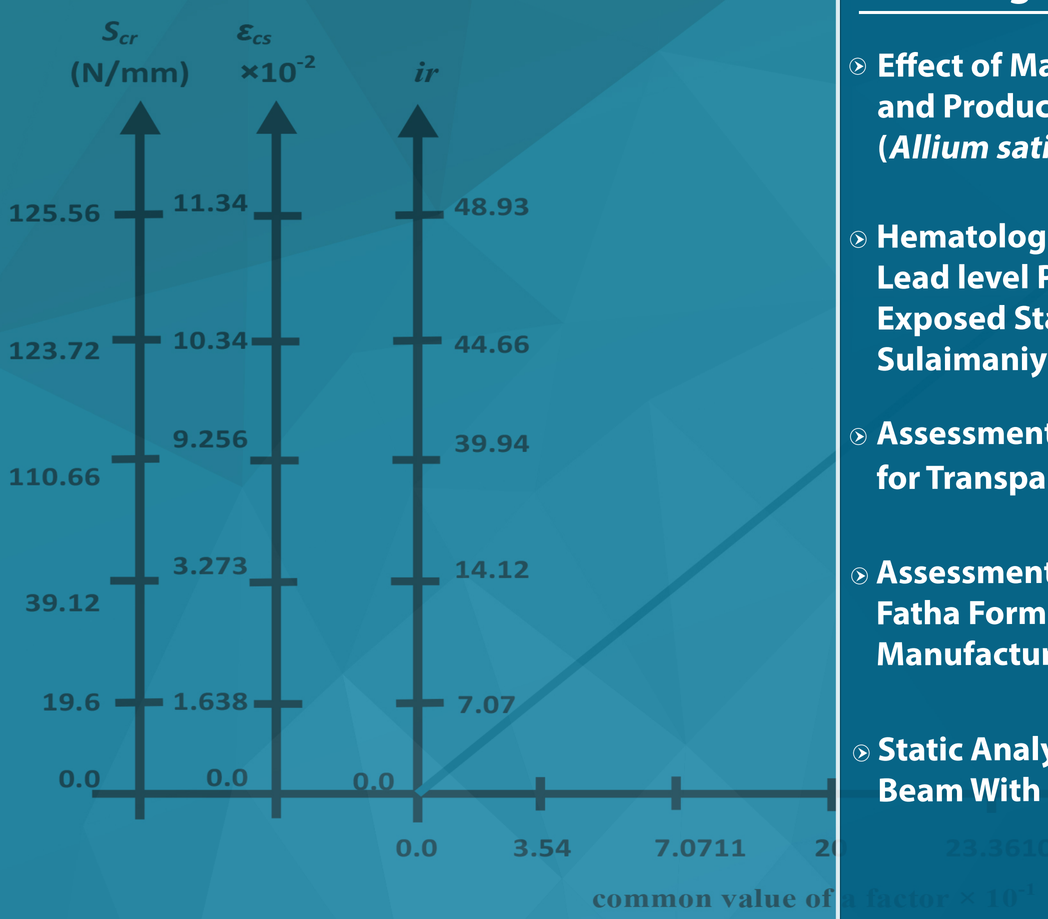

Issue Highlights

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Content

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Aro Editorial Words

You are now holding Vol 2, No 1 of Aro the Scientific Journal of Koya University. Aro is a newly established journal with ambition to become a globally recognized scientific journal with wider local impact. The editorial team is determined to keep the path of such a mission and sustain Aro's future publication.

Aro was created with a long-term visions of becoming accessible to all researchers in Kurdistan and beyond, and covering a wide range of scholarly disciplines in sciences. The focus of the journal is to reflect that of the Koya University, namely promoting scientific knowledge and research in Kurdistan. Aro aspires to become a channel for exchange of research by establishing academic connections between scholars.

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The warm response from researchers, academics and professionals made our task of creating an editorial board a relatively easy one. It is clear that having a dedicated and well organized editorial board for the journal is only one side of the coin. The other is the ability to attract submissions of quality research and scholarly work. We are thankful to all of those who put their trust in Aro and presented their original research work for publication in Vol 2, No 1 of the journal, as well as, our thanks are extended to the eleven peer-reviewers from the universities worldwide for their efforts in reviewing this issue of Aro publications.

Your support and feedback are invited and appreciated.

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Effect of Magnesium Salts on Growth and Production of Garlic (*Allium sativum* L.)

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***Abstract*—A Randomized Complete Block Design (R.C.B.D.) experiment with three replicates was conducted to investigate the effect of foliar application of magnesium salts on growth, yield components and some inorganic minerals of leaves of garlic (*Allium sativum* L.) local variety. The salts ($MgSO_4.7H_2O$, $Mg(NO_3)_2.6H_2O$ and $MgCl_2.6H_2O$) addition to untreated plants as control. The concentration of Mg were used was constant (1.97 g Mg. L_{-1} which comes from 2% $MgSO_4.7H_2O$). The results revealed that vegetative growth of garlic was affected significantly by magnesium salts. Highest number of leaves was found in plants treated with $MgCl_2$, the treatment which gave the lowest plant height, each of $MgSO_4$ and $Mg(NO_3)_2$ had the highest shoot dry weight. Foliar spraying with $Mg(NO_3)_2$ produced highest shoot dry matter percent and highest percent of leaves Phosphorus leaves content, significantly compared to other treatments. The results showed that spraying plants with $Mg(NO_3)_2$ and $MgSO_4$ improved yield components where head diameter , head weight, cloves number per head and bulbs yield were increased. Foliar spray with $MgSO_4$ had a significant effects on head scale thickness, whereas there were non-significant effects between different Magnesium salts spraying on each of clove dry matter and percent of TSS content. This study concluded that spraying plants with $MgSO_4$ or $Mg(NO_3)_2$ twice (45 days after planting and a month later) increased garlic yield and yield quality.**

***Index Terms*— Foliar, garlic, magnesium salts, yield.**

I. Introduction

Garlic (*Allium sativum* L.) belongs to Alliaceae family and is the second most widely used cultivated bulb crop after onions (Hasan, 2000). Garlic is used as a spice, seasonings and flavoring for foodstuff involving both green tops and bulbs, garlic is also cultivated for its medicinal properties (Mayeux, et al., 1998; Sterlin and Eagling, 2001). Plant growth and productivity is adversely affected by various biotic and abiotic factors, nutrients are one of the major abiotic factors, which adversely affects crop growth and yield. It is well known that the use of fertilizer helps in production and is a somewhat quick method for achieving maximum yields (Naruka, 2000). The trend toward higher yields also increases the requirements for nutrients including magnesium which can be applied either to the soil or as a foliar spray at the form of deferent kinds of salts like sulfate, nitrate and chloride. Recovery from Mg deficiency by application to soil require at least two years therefore, using foliar spray is one effective method for fast recovery and uptake (Lachover and Arnon, 1966).

Plant roots uptakes inorganic ions in different rates, monovalent ions like NO_3^-, K^+ and Cl^- mobile faster than divalent ions ($SO_4^=$ and Ca^{+2}), that means plants uptake cations and anions in unequal amounts from growing medium. New barley root put in K_2SO_4 and $CaCl_2$ solutions, uptakes K^+ faster than SO_4^{-2}, therefore cations uptake was faster than anions (Hiatt, 1967). Antagonism and synergism phenomena appear clearly between deferent ions in plant nutrition, nitrate reduction in the upper part of the plant would enhance cations uptake, therefore organic anions accumulates balancing the cation charges which combined with the nitrate ions (Kirkby and Knight, 1977).

Magnesium has a unique roles in plant physiology, including a key role as the central atom in the chlorophyll molecule, consequently magnesium affects plant chlorophyll content and the production and use of carbohydrates, it is also important in the activity of a large number of enzyme systems in plants, particularly in the metabolism of carbohydrates. Magnesium is activator of several phosphorylases and carboxylases, it is serves as a link between enzyme and the

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substrate (Ibrahim, 2010 and Srivastava, 2010). Magnesium is intimately associated with the phosphorus metabolism and is particularly essential for the enzymes involved in the phosphate transfer reaction (Verma, 2008).

Sulphur is an essential plant nutrient, its role in balanced fertilization and consequently in crop production is being recently realized, it performs many physiological functions like synthesis of sulphur containing amino acids (methionine and cysteine), proteins, and sulpho-lipids, some other biologically important sulfur containing compounds are; glutathione (a redox agent), biotine, thiamine (both vitamins) and coenzyme A. Sulfur is also a constituent of glycosides, which impart characteristic odors and flavours to mustard, onion and garlic. It also participates in forming and stabilizing three dimensional structure of proteins as disulfide (S-S) bonds (Verma, 2008 and Abdallah, et al., 2010).

Availability of nitrogen is of prime importance for growing plants as it is a major source of protein and nucleic acid molecules. It is also an integral part of chlorophyll molecules, which are responsible for photosynthesis (Naruka, 2000). Mudziwa (2010) found that each of calcium nitrate and ammonium sulphate fertilizers increased neck and bulb circumference, bulb mass, bulb cloves and marketable yield of *Allium sativum* to 45.75 mm, 196.20 mm, 128.80 g, 34.58 cloves.bulb^{-1} and 24.56 ton.hectar^{-1} for calcium nitrate and 43.75 mm, 196.80 mm, 105.20 g, 33.54 cloves.bulb^{-1} and 27.23 ton.hectar^{-1} compare to control which gives 30.75 mm, 123.50 mm, 43.70 b, 19.08 cloves.bulb^{-1} and 19.40 ton.hectar^{-1}. In green tissues chloride uptake requires the presence of light because ATP produced in photophosphorylation is used as energy source for the active uptake of chloride (MacDonald et al. 1975). Chloride ion is a component or activator of enzymes involved in photosynthesis and cell division , and acts as an osmo-regulator (Kern and Chrispeels, 1978), and chloride with N have important role in photosystem II in photosynthesis, also Cl^- and NO_3^- increase plasma membrane turgidity therefore they positively affect N nutrition. Application of chloride-containing fertilizers has been reported to increase the availability of soil manganese, unlike other micronutrients chloride is highly mobile within the plant and easily translocated. Chloride is not toxic to plants at high concentrations, some of the non-biochemical roles of chloride in osmo-regulation may require these high concentrations (Fixen, 1993). Davenport and Bentley (2001) reported that potato percent marketable yield was lower with potassium chloride fertilizer than with potassium sulfate (84.0% and 86.3% respectively).

The aim of this study was to investigate the effect of Mg salts applied as foliar nutrition on garlic plants to determine the favorable salt for best growth and yield under the environmental conditions of the middle region of Iraq.

II. Materials and Methods

The experiment was carried out in a silty loam soil with a pH (7.70) and EC (4.20 ds.m^{-1}) in the field of the College of Agriculture, Abu-Ghraib, Baghdad-Iraq. Cloves of the local cultivar variety were planted on November 10, 2005, using Randomized Complete Block Design (R.C.B.D) with three replicates. The cloves were planted on both sides of a 2 m length furrows and 10 cm between cloves. Treatments were foliar sprayed by three magnesium salts as foliar nutrition, in addition to the untreated plants as control. The first spray was done 45 days after planting, and the second was done a month later. The 2% $MgSO_4.7H_2O$ was used as standard concentration, where Mg concentration in this salt was 1.97 g Mg.L^{-1} (Al-Sahaf, 1989), and a similar concentration of Mg, when the other salts were used, was obtained as shown in Table I. Sampling was done on 10 randomly selected plants for estimating the following parameters:

A. *Growth Parameters*

The plant leaf number and parameters of shoot (height, dry weight and dry matter) were recorded.

B. *Leaves Chemical Component*

Forth leaf from apical end were collected from plants (Lorenzo and Maynard, 1980), washed by distilled water and drying at 70 C° until the weight is fixed, 0.2 g of sample powder is taken and is digested with concentration H_2SO_4 acid and perchloric acid, then transferred to 50 ml volume flask and complete the volume by distilled water (Al-Sahaf , 1989). Nitrogen was determined with microkjheldahl (Jackson, 1958), while phosphorus were determined by using Ammonium molybdenum and vitamin c (John, 1970), each of potassium and magnesium were determined by using Flamephotometer as mentioned in Al-Sahaf (1989).

C. *Yield Components*

Each of neck and head diameter were determined by Vernier, head weight, cloves number.head^{-1}, bulbs yield were recorded.

D. *Yield Quality*

Scale thickness was determined by using micro-vernier, clove dry matter was determined too, and total soluble solid (TSS) was determined by using hand-refractometer (A.O.A.C., 1970).

Data were subjected to analysis of variance (ANOVA) using the SAS program. Means were compared by the least significant difference (L.S.D.) test at the 0.05 probability (Reza, 2006).

TABLE I
MAGNESIUM SALTS USED FOR FOLIAR FERTILIZER

Material	Chemical formula	Typical composition (%)		Salt used
		Mg	Other	(g. L^{-1})
Magnesium sulfate	$MgSO_4.7H_2O$	9.86	13.01 S	20.0
Magnesium nitrate	$Mg(NO_3)_2$. $6H_2O$	9.48	10.93 N	20.77
Magnesium chloride	Mg $Cl_2.6H_2O$	11.96	34.87 Cl	15.74

III. RESULTS AND DISCUSSION

A. Effect of Magnesium Salts on Vegetative Growth Parameters

Results in Table II reveals that the number of leaves per plant was affected significantly by magnesium salts. Highest number of leaves (8.00 leaves.$plant^{-1}$) was found in plants treated with $MgCl_2$ which differ significantly compared to $Mg(NO_3)_2$, and the same treatment $MgCl_2$ gave the lowest plant height (50.40 cm) while $MgSO_4$ produced the highest plant (60.27 cm). The different Mg salts had significant effect on shoot dry weight, each of $MgSO_4$ and $Mg(NO_3)_2$ had the highest shoot dry weight (6.71 and 6.49) g respectively, whereas control and $MgCl_2$ treatments gave the lowest shoot dry weight (4.53 and 4.89) g respectively. Results in Table II indicated that foliar spraying with $Mg(NO_3)_2$ produced highest shoot dry matter percent (21.53%) significantly compared to other treatments.

TABLE II
EFFECT OF FOLIAR APPLICATION OF MAGNESIUM SALTS ON VEGETATIVE GROWTH PARAMETERS OF GARLIC

Treatments	Number of leaves.$plant^{-1}$	Plant height (cm)	Shoot dry weight (g.$plant^{-1}$)	Shoot dry matter (%)
Control	7.27 ab	52.98 ab	4.53 b	19.83 b
$MgSO_4.7H_2O$	7.27 ab	60.27 a	6.71 a	18.79 b
$Mg(NO_3)_2$. $6H_2O$	6.80 b	58.72 ab	6.49 a	21.53 a
Mg Cl_2. $6H_2O$	8.00 a	50.40 b	4.89 b	18.53 b

A same letter in the column indicates that there is no significant difference ($p<0.05$).

These results were expected since plants are very responsive to Mg fertilization because of Mg roles in chlorophyll synthesis (Ibrahim, 2010) and activation of a number of enzymes such as kinases, Ribulose 1, 5 biphosphate carboxylase (calvin cycle) and phosphoenol pyruvate carboxylase (C3-plants pathway of CO_2 fixation) (Bidwell, 1979). However, $MgCl_2$ gave the greatest number of leaves.plant-1, this may be due to the companion ion chloride as regarded an activator to photosynthetic enzymes, cell division, and osmoregulator (Kern and Chrispeels, 1978) so it expected to promote the growth of buds. Vigorous vegetative growth resulted from $MgSO_4$ salt may be attributed to companion ion S and its role in increasing chlorophyll concentration and growth throughout the season (Hu, Sparks and Evan, 1991). Shoot dry matter percent was the greatest in plants treated with $Mg(NO_3)_2$, nitrogen nutrition (as companion ion) may result in greater vegetative growth, increases in nitrogen concentration in sprays resulted in increase in biomass production with significant increase in shoot growth (Shiralipour, et al., 1981). Farooqui, et al. (2009) also found that application of 200 kg nitrogen ha^{-1} significantly increased the garlic plant height, number of leaves per plant, neck thickness, bulb diameter, number of cloves per bulb, fresh weight of 20 cloves, dry weight of 20 cloves , fresh weight of bulb, dry eight of bulb and bulb yield. Availability of nitrogen is of prime importance for growing plants as it is major and indispensable constituent of protein and nucleic acid molecules, it is an integral part of chlorophyll molecules, which are responsible for photosynthesis, an adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of available inputs finally leading to higher productivity. The findings of this investigation are in close conformity with those of Naruka and Dhaka (2001) and Yadav (2003).

B. Effect of Magnesium Salts on Leaves Chemical Component

Magnesium salts spray had only a significant effects on percent of phosphorus leaves content (Table III), where $Mg(NO_3)_2$ salt increased this percent significantly to 0.95% compared to other treatments. Whereas there were non-significant effects between different Magnesium salts spraying on each of N, K and Mg leaves content.

This result agree with the results of Romani and Maguire (2002) whom indicated that Mg has a role in increasing P uptake and its transport through plant, also it regulates plant hormones movement. This increase in P concentration may also due to increases in N concentration in this treatment (Shiralipour, et al., 1981) those researchers found that linear increase in shoot and root phosphorus content where observed when N concentration was increased.

TABLE III
EFFECT OF FOLIAR APPLICATION OF MAGNESIUM SALTS ON GARLIC LEAVES CHEMICAL COMPONENTS

Treatments	Leaves content of			
	N (%)	P (%)	K (%)	Mg (%)
Control	1.20 a	0.64 b	3.07 a	1.06 a
$MgSO_4.7H_2O$	1.15 a	0.68 b	3.02 a	0.92 a
$Mg(NO_3)_2$. $6H_2O$	1.17 a	0.95 a	3.11 a	1.14 a
Mg $Cl_2.6H_2O$	1.11 a	0.70 b	3.31 a	0.98 a

A same letter in the column indicates that there is no significant difference ($p<0.05$).

C. *Effect of Magnesium Salts on Yield and the Yield Components*

The results in Table IV clearly showed that spraying plants with any source of Mg salt (except $MgCl_2$) improved both of neck diameter and yield components where head diameter, head weight, cloves number per head and bulbs yield were increased. Increasing bulb yields in $Mg(NO_3)_2$ and $MgSO_4$ treatments were coincided with increasing the head diameter, head weight and cloves number per head. This means that both Mg salts had significant effects on garlic plant yield.

This results agreed with Farooqui, et al. (2009) whom found that application of 60 kg $S.ha^{-1}$ significantly increased garlic yield attributes like neck thickness, bulb diameter , number of cloves per bulb, fresh weight of 20 cloves, dry weight of 20 cloves, fresh weight of bulb, dry weight of bulb and bulb yield in comparison to lower doses of sulphur. Overall increase in growth attributes may be due to sulphur increasing the root system of the plants which might have resulted in an increased uptake of nutrients and were used in photosynthesis, these results agree with Randle and Bussard (1993), Sadarea, et al. (1997), Jaggi and Dixit (1999) and Jaggi (2004).

TABLE IV
EFFECT OF FOLIAR APPLICATION OF MAGNESIUM SALTS GARLIC YIELD AND YIELD COMPONENTS

Treatments	Neck diameter (cm)	Head diameter (cm)	Head weight (g)	Cloves number. $head^{-1}$	Bulbs yield ($Ton.hectare^{-1}$)
Control	11.10 b	56.60 ab	58.49 b	36.92 b	16.11 bc
$MgSO_4.7H_2O$	15.27 a	63.59 a	82.08 a	39.25 ab	21.53 a
$Mg(NO_3)_2.6H_2O$	15.35 a	61.42 a	78.56 a	46.27 a	20.66 ab
$Mg Cl_2. 6H_2O$	12.01 b	52.13 b	49.97 c	34.87 b	12.92 c

A same letter in the column indicates that there is no significant difference ($p<0.05$).

D. *Effect of Magnesium Salts on Yield Quality*

Magnesium salts spray had only a significant effects on head scale thickness (Table V), where $MgSO_4$ salt increased this parameter significantly to 38 micron, while the lowest value recorded in plants sprayed with $Mg(NO_3)_2$ salt and control treatments. Thus increasing scale thickness mean increasing the head protectively especially from disease like *Fusarium* sp. (Holz and Knox-Davies, 1985). There were non- significant effects between different Magnesium salts spraying on each of clove dry matter and percent of cloves TSS content. This result certain the avoid of nitrogen applications after bulbing commences, as this can result in softer bulbs with shorter shelf life (Engeland, 1991).

TABLE V
EFFECT OF FOLIAR APPLICATION OF MAGNESIUM SALTS ON QUALITY CHARACTERISTIC OF GARLIC

Treatments	Scale thickness (micron)	Clove dry matter (%)	TSS (%)
Control	0.28 c	44.80 a	36.50 a
$MgSO_4.7H_2O$	0.38 a	45.65 a	37.28 a
$Mg(NO_3)_2. 6H_2O$	0.27 c	47.96 a	35.72 a
$Mg Cl_2.6H_2O$	0.33 b	43.96 a	36.67 a

A same letter in the column indicates that there is no significant difference ($p<0.05$).

IV. CONCLUSION

Conclusion could be made that spraying plants with $MgSO_4$ and $Mg(NO_3)_2$ twice (45 days after planting and other a month later) could increase yield, also Mg with its companion ion had great influence on growth and productivity of garlic.

REFERENCES

Abdallah, M., Dubousset, L., Meuriot, F., Etienne, P., Avice, J.C. and Ourry, A., 2010. Effect of mineral sulphur availability on nitrogen and sulphur uptake and remobilization during the vegetative growth of Brassica napus L. *J Exp Bot.*, 61(10), pp. 2635–2646.

Al-Sahaf, F.H., 1989. *Applying Plant Nutrition*. Baghdad. Dar Al-Hikma.

A.O.A.C. 1970. *Official Methods of Analysis*. 11th ed. Washington. D.C. Association of the official analytical chemist.

Bidwell, R.G.S., 1979. *Plant Physiology*. 2nd edition. New York. Macmillan Publishing Co. Inc.

Davenport, J.R. and Bentley, E.M., 2001. Does potassium fertilizer form, source and time of application influence potato yield and quality in the Columbia Basin. *Amer. J. of Potato Res*. 78(4), pp.311-318.

Engeland, R. L., 1991. *Growing great garlic: the definitive guide for organic gardeners and small farmers*. Okanogan, HSA Library.

Farooqui, M.A., Naruka, I.S., Rathore, S.S., Singh, P.P. and Shaktawat R.P., 2009. Effect of nitrogen and sulphur levels on growth and yield of garlic (Allium sativum L.) *As. J. Food Ag-Ind.* Special Issue, pp.18-23.

Fixen, P.E., 1993. Crop responses to chloride. *Advanced in Agronomy*. 50, pp. 107-150.

Hasan, A.A., 2000. *Onion and Garlic. Series of Vegetable group, Production Technology and Development Agricultural Practices*. 1st ed. Cairo. Al-Qahira Arabic House for Publishing and Distribution.

Hu, H.., Sparks, D., Evan, J.J., 1991. Sulfur deficiency influences vegetative growth, chlorophyll and element concentrations, and amino acids of pecan. *J. Amer. Soc. Hort. Sci.* 116(6), pp.974-980.

Hiatt, A.J., 1967. Reactions in vitro of enzymes involved in CO_2 fixation accompanying salt uptake by barley roots. *Z-Pflanzenphysiol*. 56, pp.233-245.

Holz, G. and Knox-Davies, P.S., 1985. Natural sugars present in different parts of onion bulbs at different growth stages in relation to pectic enzyme production by Fusarium oxysporum f. SP. cepae. *Phytophylactica*. 17(3), pp. 157-161.

Ibrahim, H.I.M., 2010. *Plant Samples: Collection and Analysis*. Cairo, Dar Al-Fajr for Publishing and Distribution.

Jackson, K.L., 1958. *Soil Chemical Analysis*. Englewood, Prenticaints Hall Inc.

Jaggi, R.C., 2004. Effect of sulphur levels and sources on composition and yield of onion (Allium cepa*)*. *Indian Journal of Agricultural Science*, 74(4), pp.219-220.

Jaggi, R.C. and Dixit, S.P., 1999. Onion *(Allium cepa)* response of sulphur in representative vegetable growing soils of Kangra Valley of Himachal Pradesh. *Indian Journal of Agricultural Science*, 69(4), pp.289-291.

John, M.K., 1970. Colorimetric determination of phosphorus in soil and plant materials with ascorbic acid. *Soil Science*, 109(4), pp.214-220.

Kern, R. and Chrispeels, M.J., 1978. Influence of the axis on the enzymes of protein and amide metabolism in the cotyledon of mung bean seedlings. *Plant Physiology*, 62(5), pp.815-819.

Kirkby, E.A. and Knight, A.H., 1977. The influence of the level of nitrate nutrition on ion uptake and assimilation, organic acid accumulation and cation-anion balance in whole tomato plants. *Plant Physiology*, 60, pp.349-353.

Lachover, D.O. and Arnon, I., 1966. Observations on the relationship between heavy potassium deficiency and poor quality of several agricultural products of major crops. In: Potassium and the quality of agricultural products. *Proc. 8th Cong. Intern. Potash Institute*, Berne, pp.439-464.

Lorenzo, O.A. and Maynard, D.N., 1980. *Knots Handbook for Vegetable Growers*. 2nd Edition. New York, Willy.

MacDonald, I.R., Macklon, A.E. and Macleod, R.W., 1975. Energy supply and light enhanced chloride uptake wheat laminae. *Plant Physiology*, 56(5), pp.699-702.

Mayeux, P.R., Agrawal, K.C., Tou, J.S., King, B.T., Lippton, H.L., Hyman, A.L., Kadowiz, P.J. and Namara, D.B., 1998. The pharmacological effects of allicin, a constituent of garlic oil. *Agents Actions*, 25, pp.182–190.

Mudziwa, N. 2010. *Yield and Quality responses of Egyptian white garlic (Allium sativum L.) and wild garlic (Tulbaghia Violacia Harv.) to nitrogen nutrition*. MSc. University of Pretoria.

Naruka, I.S., 2000. *Effect of row spacing and nitrogen fertilization on growth, yield and quality of garlic cultivars*. Ph.D. RAU, Bikaner.

Naruka, I.S. and Dhaka, R.S., 2001. Effect of row spacing and nitrogen fertilization on growth, yield and composition of bulb in garlic *(Allium sativum L.)* cultivars. *Journal of Spices and Aromatic Crops*, 10(2), pp.111-117.

Randle, W.M. and Bussard, M.L., 1993. Pungency and sugars of short day onions as affected by S nutrition. *Journal of the American Society for Horticultural Sciences*, 118(6), pp.766-70.

Reza, A.H., 2006. *Design of Experiments for Agriculture and the Natural Sciences*. New York. Chapmann & Hall.

Romani, A.M. and Maguire, M.E., 2002. Hormonal regulation of Mg^{+2} transport and homeosis in eukaryotic cell. *Biometals*. 15(3), pp.271-283.

Sadarea, S.S., Malavia, D.D., Khanapara, V.D., Dudhatra, M.G., Vyas, M.N. and Mathukia, R.K., 1997. Irrigation and nutrient requirement of garlic *(Allium sativum L.)* under South Saurashtra region of Gujrat. *Indian Journal of Agricultural Sciences*, 67(9), pp.402-403.

Shiralipour, A., Haller, W.T. and Garrard, L.A., 1981. Effect of Nitrogen sprays on biomass production and Phosphorus uptake in water hyacinth. *J. Aquat. Plant Manage*., 19, pp.44-47.

Srivastava, H.S., 2010. *Plant Physiology, Biochemistry and Biotechnology*. Meerut. Rastogi Publications.

Sterling, S.J. and Eagling, R.D., 2001. Agronomic and allicin yield of Australian grown garlic *(Allium sativum)*. *Acta Hort*., 555, pp.63–73.

Verma, V., 2008. *Textbook of Plant Physiology*. New Delhi. Ane Books India.

Yadav, P.K., 2003. Effect of nitrogen and potassium on growth and yield of garlic *(Allium sativum L.)* in western Rajasthan. *Haryana Journal of Horticultural Science*, 32(3-4), pp.290-291.

Hematological, Biochemical and Blood Lead Level Profile among Gasoline Exposed Station Workers in Sulaimaniya City

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***Abstract*—Occupational exposure to toxic fumes of leaded gasoline has become a major public health concern. These fumes contain tremendous life threatening toxins, which can cause abnormal alterations in the functioning of many vital organs. The current study intended to find out any changes in the hematological and biochemical profile in correlation to the Blood lead levels among individuals occupationally exposed to gasoline and gasoline vapors as a fist line risk group. The mean Blood lead level among gasoline station workers ($6.2 \pm 5\mu g/dL$), was significantly higher ($P = 0.017$) than controls (2.1 ± 6.4 μg/dL), and there was a significant ($P = 0.003$) increase in Blood lead level ($10.6 \pm 3.9\ \mu g/dL$) of smoking workers compared to non-smoking workers. The latter is above the permitted value for adult individuals. The workers had higher ($P = 0.01$) concentration of hemoglobin ($15.9\ gm/dL$), whereas, other hematological counts were within the normal limits. Serum alkaline phosphatase and uric acid were significantly higher among the workers (338 ± 49.5 and 6.1 ± 1.7) with P-value of (0.0001 and 0.038 respectively), whereas, no statistically significant differences were found among serum alanine transaminase, aspartate transaminase, creatinine, cholesterol and albumin.**

***Index Terms*—Occupational exposure, leaded gasoline, hematological & Biochemical findings, gasoline station workers.**

I. Introduction

Lead (Pb) is one of the oldest chemical toxins and a harmful environmental pollutant. It is found almost everywhere (Nordic Council, 2003; Karrari, Mehrpour and Abdollahi, 2012). Although, Lead is one of the most useful industrial elements, but serves no useful function in the human body (Mahmoud, 1997). In fact, it is not degradable in nature and will thus, once released to the environment, stay in circulation. While naturally occurring, it can be released to the environment as a result of many industrial processes such as production of batteries, paints, varnishes and as anti-detonation agent in gasoline (U.S. Dep. of Health and Human Services, 2007; Cabaravdic, et al., 2010). Gasoline is the common term for petroleum fuel used mainly for internal combustion engine it is complex, volatile and contains more than 500 saturated or unsaturated hydrocarbons having from 3 to 12 carbon atoms. The Majority of its noxious risk comes from breathing exhaust fumes, evaporative and refueling emissions rather than from irregular skin contact from spills (Amal, 2009) Although, leaded gasoline is phased-out in many significant regions of the world such as, USA and Europe, lead is still used as an additive to benzene to help reduce engine knocking and boost octane ratings in many developing countries, including Iraq and Kurdistan region. Occupational exposure has become one of the characteristics of the modern life, nowadays human being are exposed to many types of environmental pollutants at different stages of their life span and at different levels. Unfortunately, the majority of them are harmful. One of the oldest harmful agents known to mankind is lead. Unfortunately, day by day the amount of air emissions of lead and other harmful exhausts from vehicles are now increasing in an unacceptable manner in Iraq and Kurdistan, because of an increased motorization and urbanization, which ultimately, leads to excessive emission of more and more noxious gases and other unsafe fumes. Despite all of these hazards, yet, we lack a clear and strict regulation to maintain a healthy occupational and general public environment.

In Sulaimaniya city, leaded gasoline station workers are occupationally exposed to many hazardous and noxious fumes on a daily basis during their work hours at the filling stations. They almost lack the protective measures at work place, because of either their carelessness or the equipments are not provided, or as a result of the lack of education about the health issues of daily leaded gasoline and benzene exposure. In order to give awareness about some one's recent exposure to this metal, blood lead level (BLL) provides the best parameter (Lynda, et al., 2011). According to the Centers for Disease Control and Prevention (CDC), an elevated BLL is defined as $\geq 10\ \mu g/dL$. While In children, BLLs must not exceed 5 μg/dL. An increase in BLL $\geq 10\ \mu g/dL$ or even lower, have been associated with developmental delays, deficits in behavioral functioning, decreased stature, and diminished hearing acuity and difficulty learning (Amal, et al.,

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2009; Hamad, 2008). In fact, no safe BLL in children has been identified (CDC, 2013). Exposure to leaded gasoline can be harmful to most body systems, absorbed primarily through respiratory and digestive routes and interfering with cellular function and metabolism. Elevated BLL produce harmful effects on hematopoietic, hepatic, renal, reproductive, and gastrointestinal systems (Hernandez, et al., 2003). Many recent studies concluded that chronic exposure to lead is associated with adverse effects on renal function impairment and increased serum uric acid level in laboratory animals and man (Ali Khan, 2013; Alasia, Emem-Chioma and Wokoma, 2010). There is controversy concerning the direction of change of renal function parameters following chronic lead intoxication. Chronic exposure to high BLL leads to adverse effects on renal function and the hematopoietic system in both animals and humans (Odigie, et al., 2004; Elwood and Gallacher, 1984). Others concluded that Chronic lead exposure causes hypertension, abnormal changes in lipid profile, atherosclerosis and cardiovascular disease, which are associated with, and, in part, due to oxidative stress(Zhenmin, et al., 2004; Lynda, et al., 2011). Concerning the hematological adverse effects many studies concluded a decrease in Hemoglobin content and hematocrit value in parallel manner with decrease in red blood cell count. , an increase in, the WBC count (Abdel Aziz, Al Agha and Shehwan, 2006).

The International Agency for Research on Cancer (IARC) has determined that inorganic lead is probably carcinogenic to human (U.S. Dept. of Health and Human Services, 2007). According to The World Health Organization (WHO), Human exposure to gasoline has been associated with a range of acute and long-term adverse health effects and diseases, including cancer and aplastic anemia. Chromosomal aberrations and sperm abnormalities. (WHO, 2010). On the other hand, benzene in the regular fuel, which is a widespread environmental chemical associated with increased risk of hematological malignancies, particularly with acute myeloid leukemia (U.S. EPA, 2009; Carugno, et al., 2012). Based on the above literature about the health risks of leaded gasoline exposure, the current study intended to find out any changes in the hematological and biochemical profile in correlation to the BLL among persons occupationally exposed to gasoline and gasoline vapors as a fist line risk group.

II. Materials and Methods

The present study was conducted from January 2013 through July 2013, and intended to recognize the risk factors associated with leaded gasoline exposure and to determine biochemical and hematological profile among gasoline station workers in Sulaimaniya city. The methodology used in this study involved questionaries' data gathering, as well as, collection, preparation, and storage of the blood samples. It also included the different laboratory tests that were used to investigate biochemical, hematological and BLL profile among occupationally exposed gasoline station workers. The participants were given a prior insight about the aim of the study and the contribution was elective. Also, each of them received a copy of their results with some interpretation. The study sample included 34 randomly selected filling-pump workers at ten gasoline stations located in Sulaimaniya city. Having mean age of (32 ± 11) years with average serving of (4 ± 4.7) years in gasoline stations and average daily work of about 7 hours. The questionnaire for each subject was filled included, age, duration of work, safety measures, smoking habits and self-reported complains. Conversely, sixteen individuals with average age of (34 ± 9) years from general population of Sulaimaniya residents who almost have no history of being worked at gas stations and matching the experimental group in age and sex were enrolled as a control group. Complete blood counts were obtained from the whole blood specimens at the same day of collection, using automated hematology analyzer from SWELAB, Sweden.

Serum Alanine Transaminase (ALT), Aspartate Transaminase (AST), alkaline phosphatase (ALP), creatinine, albumin and uric acid were analyzed in Medya clinical laboratory by using KENZA 240 TX/ISE chemical auto analyzer, BioLabo, France. While the BLL were obtained by diluting one milliliter of serum in 9 milliliter of deionized water, later the value of each sample were obtained by using Inductively Coupled Plasma-Optical Emission Spectrometry, OPTIMA 2100DV from Perkin Elmer. The statistical analysis used was included independent-test to compare means. The data were analyzed by using the Statgraphics Plus Version 4.0. The P-values less than 0.05 were considered significant.

III. Results

A. *Blood Lead Level*

Out of the 12 stations, the workers at 10 stations accepted to give blood samples for BLL, biochemical and hematological analysis. In general, the protective measures in the stations were very low or sometimes absent. This, in turn, may contribute in development of health complaining of some workers. The most frequently self-reported health complaints were respiratory issues; especially dyspnea, fatigue, cough, irritability, red eyes and head ache. It is worthy to be mentioned that the majority of these complaints were appeared after the period of working at gasoline stations. The results of the present study revealed, a statistically significant increase $(P - value\ =\ 0.017)$ in the mean BLL value among gasoline station workers $(6.2\ \pm\ 5\mu g/dL)$, when compared to mean BLL of control group $(2.1\ \pm 6.4\ \mu g/dL)$, as shown in Fig. 1.

Among the studied sample of workers, the smoking individuals $(n = 7)$ had higher $(P = 0.003)$ mean of BLL $(10.6 \pm 3.9\ \mu g/dL)$, as well as, the symptoms were more intensive among them when compared to non-smoking workers $(4.8 \pm 5.7\ \mu g/dL)$. See Fig. 2.

The BLL distribution among both studied groups are presented in Table I. A remarkable percentage of the workers had their BLL located within the higher ranges. Forty one percent of workers had BLL in between 1-5 µg/dL, while only 6% of controls having the same BLL range. The BLL range of 5-10 µg/dL was presented in 26% and 6% of workers and controls successively. As well as, 26% of workers had BLL located between 10-20 µg/dL versus 12% of controls.

Labor duration and exposure of gasoline station workers in relation to their BLL values are represented in Fig. 3. As an average, the workers were served for (4 ± 4.7) years in gasoline stations along with average daily work of about (7) hours. As a percentage fraction, 40% of workers served for more than 5 years.

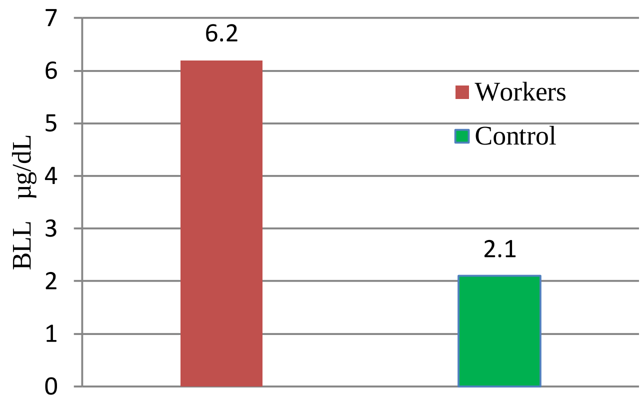

Fig. 1. Mean BLL values between workers and control group

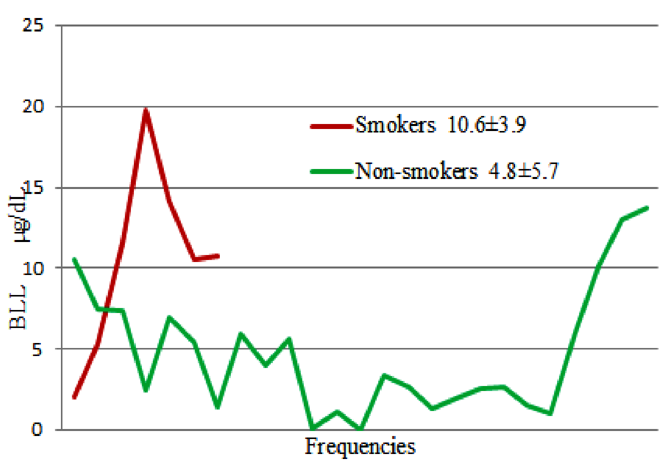

Fig. 2. Comparison of BLL between smoking and non-smoking workers

TABLE I
DISTRIBUTION OF BLL VALUES OF BOTH STUDIED GROUPS

BLL µg/dL	Control n (%)	Workers n (%)
<1	12(75)	2(5.88)
1-5	1(6.25)	14(41.2)
5-10	1(6.25)	9(26.5)
10-20	2(12.5)	9(26.5)

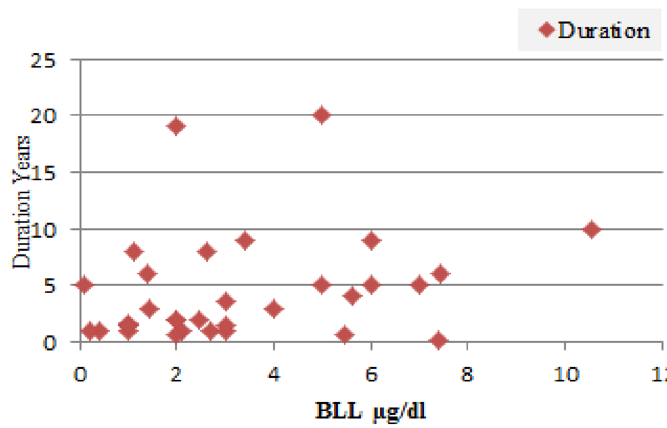

Fig. 3. Blood lead levels of workers in relation to their work period (n=34).

B. Hematological profile

Anti-coagulated fresh blood samples were analyzed at the same day of collection for obtaining complete blood count; the data are presented in Table II.

TABLE II
MEAN VALUES OF HEMATOLOGICAL PARAMETERS OF BOTH STUDIED GROUPS

Subjects	Parameter	Mean	SD*	P-Value	Level of Sig.
Controls (n=16)	Hgb	15.1	19		
	RBC	5.2	0.29		
	HCT	44.8	2.6		
	MCH	28.7	1.3		
	MCHC	34.1	1.27		
	TWBC	8066	1769		
	PLT	199	36.1		
Workers (n=34)	Hgb	15.9	1.02	0.01	**
	RBC	5.4	0.38	0.09	Non
	HCT	44.2	3.3	0.39	Non
	MCH	29.7	2.4	0.61	Non
	MCHC	36.1	1.07	0.42	Non
	TWBC	7400	1649	0.15	Non
	PLT	212	36.4	0.18	non

*standard deviation, ** significant.

The statistical analysis showed significant increases (P = 0.01) in hemoglobin (Hgb) content of the worker's blood in comparison to controls. Oppositely, no significant differences were found between the total red blood cell count (RBC), hematocrit value (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), blood platelet count (PLT), mean platelet volume (MPV),total and differential white blood cells (WBC).

C. Biochemical parameters

Liver function tests

The activities of some liver enzymes in controls and gasoline station workers are shown in Fig. 4. The mean level of serum

ALP of the workers (338 ± 49.5) was significantly higher ($P = 0.0001$), in comparison to the control group (257 ± 43.6).Whereas, no statistically significant differences ($P = 0.46$ and $= 0.66$) were found between the mean levels of the ALT and AST (49 ± 80 and 33 ± 23.8, respectively). As well as, no statistically significant ($P = 0.78$) differences found between the total cholesterol of the workers and control group (195 ± 29 and 198 ± 34.9, respectively).

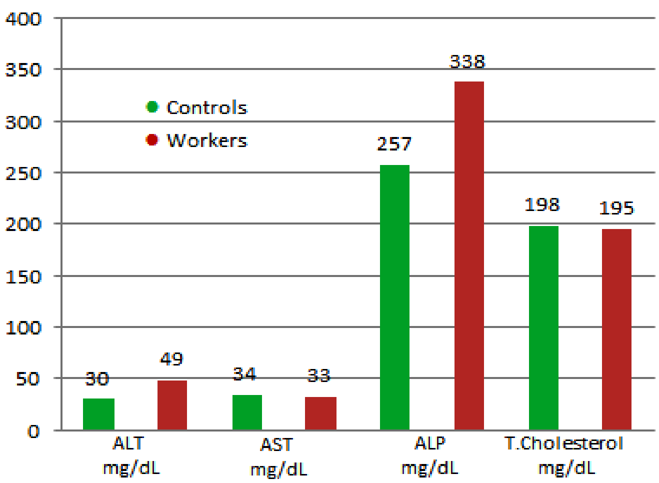

Fig. 4. Mean values of some liver function parameters

Renal function

The mean level of serum uric acid in gasoline station workers (6.1 ± 1.7) was statistically higher ($P = 0.038$), compared to the control group (4.9 ± 0.87), whereas, no statistically significant differences ($P - value = 0.08$) was found between the mean level of serum creatinine in both workers and control group (0.7 ± 0.6 and 0.8 ± 0.9, respectively). As well as, no statistically significant ($P = 0.18$) differences found between the serum albumin of the workers and control group (4.8 ± 36.4 and 4.5 ± 36, respectively).as shown in Fig. 5.

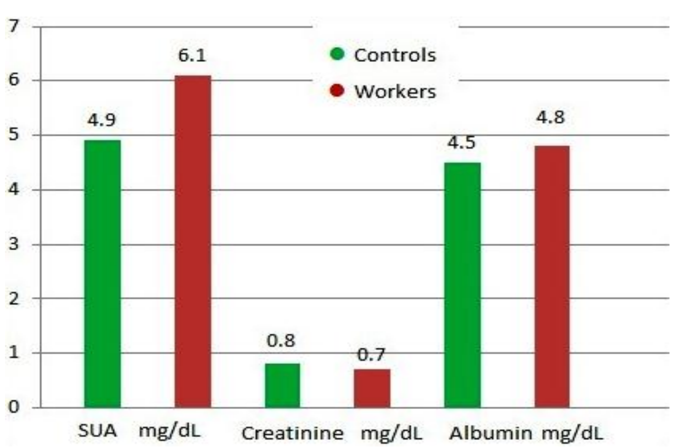

Fig. 5. Mean values of some renal function-related parameters among both studied groups.

IV. Discussion

Sulaimaniya city experience serious and continuously increasing environmental and occupational problems. Gasoline station workers are regularly exposed to many hazardous toxins and noxious vapors, among the most risky toxins are those of lead and benzene fumes. Which they can cause abnormal alterations in the functioning of many vital organs (Abdel Aziz, Al Agha, and Shehwan, 2006; Ali Khan et al., 2011) and they are associated with increased risk of hematological malignancies, particularly with acute nonlymphocytic (myeloid) leukemia (Baan, 2009).

Unfortunately, the majority of the workers are neglecting or lacking the protective safety measures such as; facemasks, protective cloths, gloves and washing themselves after finishing their working shift. In turn, this carelessness makes them more susceptible to those toxic fumes. The results in the present study indicate that BLL are significantly higher among gasoline stations workers ($6.2\ \mu g/dL$) when compared to control subjects ($2.1\ \mu g/dL$). Though, according to CDC these values are within accepted level of BLL. In a similar study done in Basrah-Iraq, Al-Rudainy, (Al-Rudainy, 2010) found an elevated BLL ($14.1 \mu g/dL$), among benzene workers, which is higher than the results of current study, this differences may belongs to the geographical variations and toxic exposures of Gulf war weapons. A part of this increase may belong to the regular daily inhalation of leaded benzene fumes and neglecting the protective measures. Non-surprisingly, among the workers of the present study, the smoking individuals had higher mean of BLL ($10.6\ \mu g/dL$), which is according to CDC is an elevated level of BLL. As well as, the clinical symptoms were more intensive among them when compared to non-smoking workers. Since the inhalation of benzene and cigarette smokes together may have augmentation effects on the accumulation pathways of lead in the body (Grandjean, Niels and Hanne, 1981).

Regarding the hematological findings, the current study showed an increase in Hbg concentration among workers when compared with the control subjects, which came in parallel with some other recent finding (Uzma, et al., 2008; Hamad, 2008 and Pesatori, et al., 2009). In contrast, the counts of RBC, HCT, MCH, MCHC, MCV, PLT, MPV, WBC and differential WBC counts, were within the normal ranges and had no significant differences with those of controls. The analysis of biochemical parameters showed a significant increase in the concentration of ALP among the workers. Alkaline phosphatase in healthy adults mainly derives from liver, bones and in lesser amount from intestine, kidneys, leukocytes and placenta. An increase in alkaline phosphatase level is frequently associated with a variety of diseases, such as intrahepatic cholestasis, extra hepatic bile obstruction, and hepatitis (Ali Khan, et al., 2013). The reason might be the regular exposure to benzene, leaded gasoline and other chemical derivatives. While no significant differences found between the levels of transaminases ALT and AST among both studied groups. These two latter enzymes are most frequently measured enzymes which reflect hepatotoxicity (Hamad, 2008; Ali Khan, et al., 2013).
In the present study serum uric acid was significantly higher among the workers. This finding is consistent with other

findings. Which may be due to degradation of purines and pyrimidines or to an increase of uric acid level by either over production or inability of excretion (Abdel Aziz, Al Agha, and Shehwan, 2006), whereas, serum creatinine and albumin were within the normal ranges and had no significant differences with those of controls. Although the overall results of the current study are generally consistent with many of previous studies, it might be much more reliable and intensive if we evaded some limitations in the method we applied such as the sample size, cost, multi-source gasoline and other interfering factors for example, allocation of different sources of lead exposure other than gasoline stations alone.

V. Conclusion

Blood lead levels are slightly elevated among gasoline station workers in Sulaimaniya city and the smoking workers had higher BLL. As well as, the workers had higher hemoglobin concentration. While other hematological parameters were within the normal ranges. The concentrations of serum ALP and SUA were significantly higher among the workers. Whereas, normal levels of the serum creatinine, albumin, total cholesterol, ALT and AST enzymes were found among them. A clear educational and protection policy is required for those who are occupationally exposed to benzene and other noxious gasoline vapors.

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References

Abdel Aziz, I.I., Al Agha, S.Z., and Shehwan, O.A., 2006. Hematological and Biochemical Studies for Gasoline Toxicity among Gasoline Workers in Gaza Strip. *Al-Aqsa Univ. J.*, (10), pp.41-55.

Alasia, D.D., Emem-Chioma, P.C. and Wokoma, F.S., 2010. Association of Lead Exposure, Serum Uric Acid and Parameters of Renal Function in Nigerian Lead- Exposed Workers. *Int. J. Occup. Environ. Med.*, 1(4), pp.182-190.

Ali Khan, A., Sultan, R., Zamani, GY. and Rahman, S.U., 2013. Biochemical and Hematological Analysis after Exposure to Hazardous Materials during Shoe Making. *Journal of Biology and Life Science*, 4(2), pp.116-28.

Al-Rudainy, L.A., 2010. Blood Lead Level among Fuel Station Workers. *Oman Medical Journal*, 25(3), pp.208-211.

Amal, K., 2009. Impact of gasoline inhalation on some neurobehavioral characteristics of male rats. *BMC Physiology*, (9)21, doi:10.1186/1472-6793-9-21

Amal, M., Akhlaque, H., Manirul, I. and Bashar, S.A., 2009. Lead Poisoning: An Alarming Public Health Problem in Bangladesh. *Int. J. Environ. Res. Public Health*, 6(1), pp.84-95.

Baan, R., Grosse, Y., Straif, K., Secretan, B., El-Ghissassi, F., Bouvard, V., et al., 2009. A review of human carcinogens—Part F: chemical agents and related occupations. *Lancet Oncol*., 10(12), pp.1143–1144.

Cabaravdic, M., Mirjana, M., Jasna, K., and Amra. 2010. Occupational Exposure of Workers at Gas Station to Inorganic Lead. *MED ARH*, 64(2), pp.107-109.

Carugno, M., Pesatori, AC., Dioni, L., Hoxha, M., Bollati, V., Albetti, B., Byun, HM., Bonzini, M., Fustinoni, S., Cocco, P., Satta, G., Zucca, M., Merlo, DF., Cipolla, M., Bertazzi, PA., Baccarelli, A., 2012. Increased mitochondrial DNA copy number in occupations associated with low-dose benzene exposure. *Environmental Health Perspectives.* 120(2), pp.210-215.

Centers of Disease Control and Protection (CDC), 2013. *Blood Lead Levels in Children Aged 1–5 Years—United States, 1999–2010*. MMWR, (62), pp.245-248.

Department of Health and Human Services, 2007. *Toxicological Profile for Lead*. [pdf] U.S.: Agency for Toxic Substances and Disease Registry. Available at <http://www.atsdr.cdc.gov/toxprofiles/tp13.pdf> [Accessed 1 November 2013].

Elwood, P.C. and Gallacher, J.E., 1984. Lead in petrol and levels of lead in blood: scientific evidence and social policy. *Journal of Epidemiology and Community Health*. 38(4), pp.315-318.

Grandjean, P., Niels, B..P. and Hanne, H., 1981. Influence of smoking and alcohol on blood lead levels. *Int. Arch Occup Environ health*. 48(4), pp.391-397.

Hamad, A.R., 2008. Some Biochemical and Hematological Alterations Associated with Lead Exposure in Gasoline Station Workers in Gaza Strip. M.Sc.thesis, the Islamic University-Gaza, Faculty of Science., pp.37-58.

Hernández-Serrato, M.I., Mendoza-Alvarado, L.R., Rojas-Martínez, R., González-Garza, C., Hulme, J.M., Olaiz-Fernández, G., 2003. Factors associated with lead exposure in Oaxaca, Mexico. *Journal of Exposure Analysis and Environmental Epidemiology*. 13(5), pp.341-347.

Karrari, P., Mehrpour O. and Abdollahi M. A., 2012. Systematic review on status of lead pollution and toxicity in Iran; Guidance for preventive measures. *DARU Journal of Pharmaceutical Sciences*, 20(1), doi: 10.1186/1560-8115-20-2.

Lynda, A., Mohamed, H., Abderrezek, T. and Seddik K., 2011. Effect of Long-term Exposure to Low or Moderate Lead Concentrations on Growth, Lipid Profile and Liver Function in Albino Rats. *Advances in Biological Research*. 5(6), pp. 339-347.

Mahmoud, L.A., 1997. Renal Effects of Environmental and Occupational Lead Exposure. *Envinm Healh Perspect*., 105(9), pp.928-939.

Ni, Z., Hou, S., Barton, CH., Vaziri, ND., 2004. Lead exposure raises superoxide and hydrogen peroxide in human endothelial and vascular smooth muscle cells. *Kidney International*. 66(6), pp.2329–2336.

Nordic Council of Ministers, 2003. *Lead Review*. Available at <http://www.who.int/ifcs/documents/forums/forum5/nmr_lead.pdf> [Accessed 1 November 2013].

Odigie, I.P., Ladipo, C.O., Ettarh, R.R and Zebu, M.C., 2004. Effect of Chronic Exposure to Low Levels of Lead on Renal Function and Renal Ultrastructure in Sd Rats. *Nigerian Journal of Physiological Sciences*, 19(1-2), pp.27-32.

Pesatori, A.C., Garte, S., Popov, T., Georgieva, T., Panev, T., Bonzini, M., Consonni, D., Carugno, M., Goldstein, B.D., Taioli, E., Fontana, V., Stagi, E., Bertazzi, P.A., and Merlo, D. F., 2009 . Early effects of low benzene exposure on blood cell counts in Bulgarian petrochemical workers. *Medicina Del Lavoro*, 100(2), pp.83-90.

Rahman, S.U., 2013. Biochemical and Hematological Analysis after Exposure to Hazardous Materials during Shoe Making. *Journal of Biology and Life Science*., 4(2), pp.116-28.

U.S. Environmental Protection Agency, 2009. *Benzene TEACH Chemical Summary*. [pdf] U.S.: EPA, Toxicity and Exposure Assessments for Children's Health.
Available at <http://www.epa.gov/teach/chem_summ/BENZ_summary.pdf> [Accessed 1 November 2013].

Uzma, N., Salar, B.M.K.M., Kumar, B.S., Aziz, N., David, M.A., and Reddy, V.D., 2008. Impact of organicsolvents and environmental pollutants on the physiological function in petrol filling workers. International Journal of Environmental Research and Public Health, 5(3), 139-46.

WHO, 2010. *Exposure to Benzene: A Major Public Health Concern*. [pdf] Geneva: WHO, Dept. of Public Health and Environment. Available at <http://www.who.int/ipcs/features/benzene.pdf> [Accessed 1 November 2013].

Assessment of Ballistic Performance for Transparent Material

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***Abstract*—A finite element method was used to investigate the ballistic behavior of Polymethylmethacrylate (PMMA) under impact loading by spherical steel projectile with different ranges of velocities. Three different target thicknesses were used in the experimental and the numerical works. A mathematical model has been used for the ballistic limit based on the experimental results. It has been found that projectile velocity and target thickness play an important role in the ballistic behavior of PMMA. A good agreement was found between the numerical, experimental, and the analytical result.**

***Index Terms*—Finite element method, ballistic impact, PMMA.**

I. INTRODUCTION

The ballistic behavior of transparent materials (ceramic and glass) was studied. Different kinds of layered composite materials were compared from the ballistic strength viewpoint. Layered composites from soda-lime silicate float glass and also sandwiches with sapphire top layer were prepared. Their ballistic strength against two kinds of (AP) ammunition were studied. A test technique and (BMES) criterion have been used to assess the ballistic performance depth of penetration (Klement, Rolc, Mikulikova, and Krestanet, 2008).

To describe the performance of polyurethane elastomeric polymer and numerical results of the penetration mechanism and depth-of-penetration a simple linear viscoelastic model has been applied to AUTODYN-2D. The perforation and penetration of the lead antimony bullet against glass-faced polyurethane elastomeric polymer resin has been studied. The resulting craters in the resin contained elongated bullet core material that had a considerable quantity of porosity. Analysis of the simulation model and the high speed photography and of penetrating a viscoelastic resin exhibited that during the primary phases of penetration, the projectile is turned inside out. Besides, the geometry of the cavity was described by the elastic relaxation of the resin that led to compression of the core material (Hazella, Edwardsa, and Longstaffa, 2009).

Research on transparent materials under impact on glass, ceramic materials and polycarbonate was studied (Straßburger, 2008). A front layer of transparent materials was impacted by a projectile with 9.5 g in mass. The impact velocity was 850 ± 15 m/s. It has been found that the resistance strength increased proportional with material thickness. With two different thicknesses the materials efficiency in terms of strength has been observed.

The mechanical behavior (static and dynamic) of commercial polymethylmethacrylate (PMMA) have been studied (Rittel and Brill, 2008). It has been found that PMMA shows brittle failure and brittle ductile transition which is similar in its rule to that noticed in brittle material.

This study deals with transparent materials that have resistance to penetration by high velocity impactors a fragments. These materials, although generally defined, have got considerable care in military investigations and industrial establishments especially for protection of the head and face area for both civilians and military personnel. The transparent materials have been used widely over the years in, defense and buildings industries, automotive, and aerospace (Laible, 1980).

This work aims to investigate numerically the ballistic behavior and the failure modes of PMMA plates under impact by a steel spherical projectile in the speed range of 78–900 m/s and compare the results with analytical and experimental ones.

II. EXPERIMENTAL WORK

A. Preparation of Test Specimens

Polymethylmethacrylate (PMMA) is a type of resins known for its low cost and moderate characteristics, so the specimens have been prepared using plates from this transparent material. The material targets were prepared to 100 x 100 mm in dimensions. A according to the standard size (ANSI/ASTM D 638-77), tensile test specimens were prepared as well (Abbud, et al., 2010). Tensile test was conducted on INSTRON test machine at 10 mm/min cross head speed. The mechanical properties for the PMMA are outlined in Table I.

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B. Ballistic Test

All tests were conducted using the test device illustrated schematically in Fig. 1. The device consisted of a barrel of 7.85 mm bore diameter and 480 mm in length. Time counter system consisting of two measuring velocity devices has been installed in front and behind the target. Each device consists of two wire grid units connected to a time counter. This system is responsible about counting the time between the wire grid units before and after the target. Spherical rigid projectile 7.8 mm in diameter and 2.05 g in mass was used. Different velocities have been used by changing the weight of gun powder charges. Targets have been installed between two rigid fixed plates. The projectile initial velocity and the residual velocity were calculated by dividing the distance between two wire grid units by the counted time.

TABEL I
Mechanical Properties of PMMA

Material	Density ρ (kg/m^3)	E (MPa)	Yield Stress σ_y (MPa)	Tensile Strength (MPa)	Poisson's Ratio υ
PMMA	1190	3280	53.8	48.3	0.28

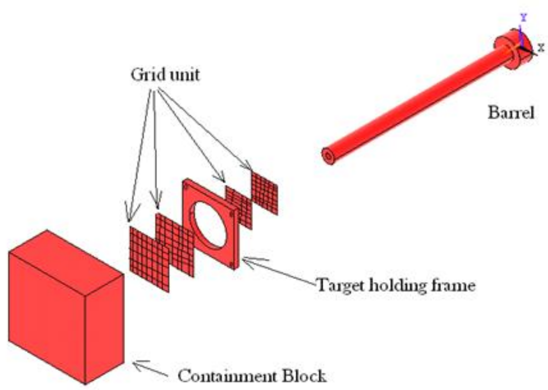


Fig. 1. Schematic drawing of the ballistic test device, re drawn based on the original scheme (Abbud, et al., 2010).

III. Analytical Model

The analytical model of the penetration and perforation of a hard projectile on a PMMA plate fixed at its rim will depend on the conservation of energy principle where the reduction of the kinetic energy of the projectile ($\Delta K.E$) is equal to the work done on the deformation of the W_E,

$$\Delta K.E = \frac{1}{2}[m(V_i^2 - V_r^2)] = W_E \qquad (1)$$

Where m is the mass of the rigid projectile, V_i and V_r are the initial and residual projectile velocities respectively W_E is the elastic work stored in the target panel during the penetration phase. (Al–Ghabban, 1996) showed that for a clamped circular plate of radius (R), subjected to a central concentrated load (P), the central deflection (W_E) may be written according to (Timoshenko and Goodier, 1982);

$$W_E = \frac{p_o^2}{2k} = \frac{3\pi\,\sigma y^2}{8E} hR^2(1-v^2) \qquad (2)$$

$$\frac{1}{2}\,mV_b^2 = \frac{3\pi\,\sigma y^2}{8E} hR^2(1-v^2) \qquad (3)$$

$$V_b^2 = \frac{2}{m}\left\{\frac{3\pi\,\sigma y^2}{8E} hR^2(1-v^2)\right\} \qquad (4)$$

Therefore the ballistic limit (V_b) is

$$V_b = \frac{2}{m}\left\{\frac{3\pi\,\sigma y^2}{8E} hR^2(1-v^2)\right\}^{\frac{1}{2}} \qquad (5)$$

Where, P_o is plastic failure load of the material, σy is yield stress, E is modulus of elasticity, h is target thickness, R is target radius and υ is poisson's ratio.

IV. Numerical Modeling

A 3D finite element modeling has been conducted for the impact pair with sufficient number of element to ensure highest possible degree of accuracy. Spherical rigid projectile was modeled with material in ANSYS-AUTODYN Library adopting the mechanical properties of the material in the experimental work. Hardened steel has been used for defining the behavior of projectile in the simulations. The projectile was considered as rigid material model and built by solid elements. So, the effect of element number and size on the projectile modeling is not significant in terms of residual velocity and deformation. A finite element model of a PMMA plate has been used 56661 brick element is shown in Fig. 2. All the periphery elements have been constrained. The PMMA plate is 100x100 mm size with three different thicknesses (4, 5 and 6 mm).

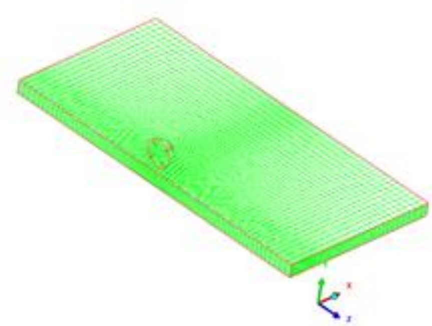


Fig. 2. Finite element model for projectile and PMMA target.

V. Results and Discussion

A. Ballistic Behavior

Generally, the fracture mechanism of PMMA plates is similar to the brittle fracture mechanism observed in the typical hard ceramic systems. A conoid fracture mode is obvious in the exit side of PMMA.PMMA illustrated a change of style of failure from brittle kind cracking to localized as the impact velocity increases. At moment of impact , the zone of impact suffers high radial and hoop stress leading to radial and circumferential cracks form over the PMMA plate causing finally the fracture of the target material in that region in a star shape. As the projectile penetrates the material with driving impulse, affected areas exhibit radial cracks makes some concentric cracks around the projectile. The projectile residual velocity V_r depends on a power function of the striking velocity and the ballistic limit as follows:

$$V_r = \sqrt{V_i^2 - V_b^2} \quad (6)$$

The experimental and analytical ballistic limit velocity V_b in (5) shows good agreement with the experimental results as shown in Fig. 3.

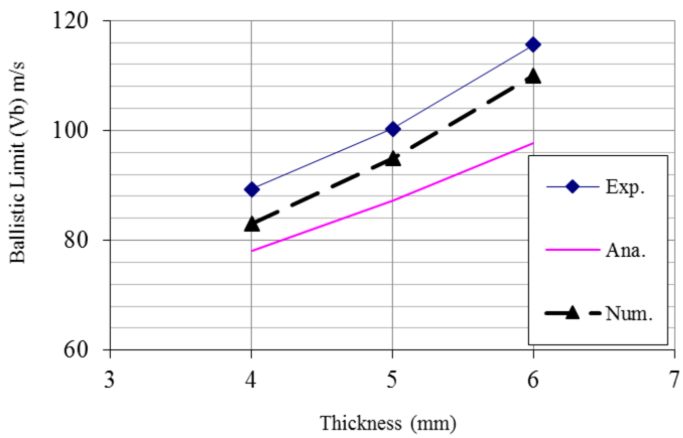


Fig. 3. Ballistic limit for PMMA.

Fig. 4, Fig. 5 and Fig. 6 illustrate the striking velocity for PMMA plates against the residual velocity for target thickness 4, 5, and 6 mm respectively. The residual velocities for numerical and experimental results have been compared versus empirical equation by Recht and Ipson (1963). It was noticed that the results were in good correlation.

B. Image Analysis

Fig. 7 shows the induced damage in the PMMA material where the red color area around the projectile represent 100% damage with radial cracks extended through the target. The localized damage diameter depends entirely on projectile velocity for specific target thickness, the higher projectile velocity the bigger localized damage diameter. Furthermore, the length of the extended radial cracks is inversely proportional with projectile velocity, besides these cracks directions depend on the projectile velocity as well.

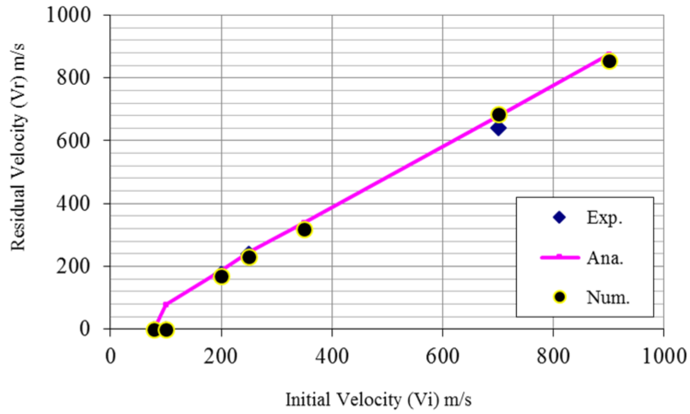


Fig. 4. Initial velocity versus residual velocity (4 mm target thickness).

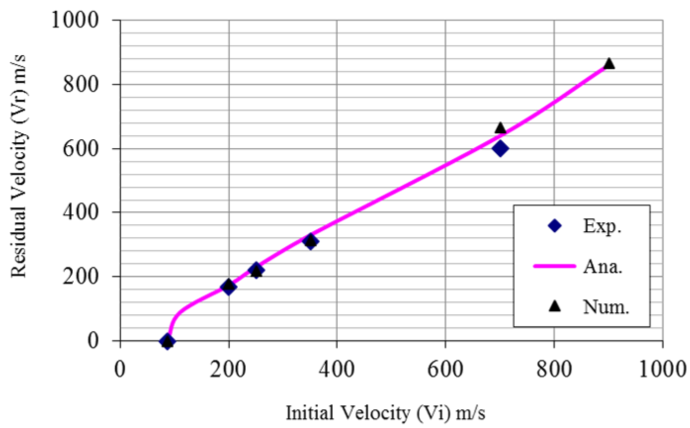


Fig. 5. Initial velocity versus residual velocity (5 mm target thickness).

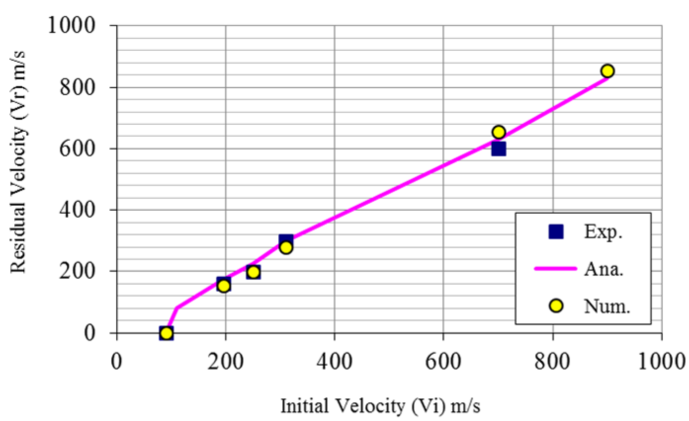
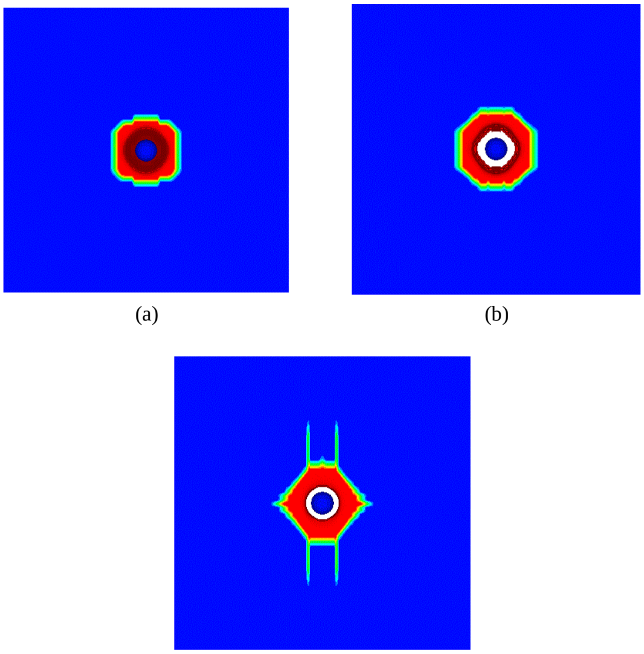


Fig. 6. Initial velocity versus residual velocity (6 mm target thickness).

Fig. 8 illustrates the comparison between the experimental photocopies and the finite element images.



(a) (b)

(c)

Fig. 7. Finite element images for 4mm target thickness, (a) 800 m/s projectile velocity, (b) 600 m/s projectile velocity and (c) 250 m/s projectile velocity.

(a) (b)

Fig. 8. PMMA target Damage for 100 m/s velocity and 4 mm target thickness; (a) Numerical result and (b) Experimental result.

VI. Conclusion

This work showed that the use of finite element method helps a lot in the representation and analysis of the behavior of transparent materials that are exposed to high velocities load with very high accuracy, which is difficult to obtain in practice. Whereby they can trust this method to reduce the time, effort and money too, especially when there is no laboratory abilities. The projectile velocity and the target thickness play a significant role in the localized damage zone, length and directions of the extended cracks. A good agreement was found between the numerical experimental and analytical result.

References

Abbud, L.H., Talib, A.R.A, Mustapha, F., Tawfigue, H., and Najim, F.A., 2010. Behavior of transparent material under high velocity impact. *International Journal of Mechanical and Materials Engineering*, 5(1), pp.123-128.

Al–Ghabban, I.A.H., 1996. *Analytical model for the behavior of multi–layered targets under projectile impact*. Ph.D. University of Technology.

Hazella, P.J., Edwardsa, M.R., and Longstaffa, H., 2009. Penetration of a glass-faced transparent elastomeric resin by a lead–antimony-cored bullet. *International Journal of Impact Engineering*, 36 (1), pp.147–153.

Klement, R., Rolc, S., Mikulikova, R., and Krestan, J., 2008. Transparent armour materials. *Journal of the European Ceramic Society*, 28(5), pp.1091–1095.

Laible, R.C, 1980. *Ballistic materials and penetration mechanics*. Amsterdam: Elsevier Scientific Publishing Co.

Recht, R.F. and Ipson, T.W., 1963. Ballistic perforation dynamics. *Journal of Applied Mechanics*, 30, pp.384–390.

Rittel, D., and Brill, A., 2008. Dynamic flow and failure of confined polymethylmethacrylate. *Journal of the Mechanics and Physics of Solids*, 56, pp.1401–1416.

Straßburger, E., 2008. Ballistic testing of transparent armour ceramics. *Journal of the European Ceramic Society*, 29, pp.267–273.

Timoshenko, S., and Goodier, J., 1982. *Theory of Elasticity*. 3rd Ed. Tokyo: McGraw-Hill.

Assessment of Some Clay Deposits from Fatha Formation (M. Miocene) for Brick Manufacturing in Koya Area, NE Iraq

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***Abstract*— This paper deals with the evaluation of physical, chemical and mineralogical properties of claystone sediments of Miocene age (Fatha Formation) and their suitability to use them as raw materials in manufacturing of building clay brick in Kurdistan (Koya city). The study based on the field reconnaissance for three sites of claystones which were selected from three different locations within Fatha Formation in Koya city, includes Haibat-Sultan area, Koya-Sulaimania road and central of Koya city. The clay samples were subjected to particle size distribution, chemical composition, mineralogical analysis, plasticity index and XRD tests. Clay tiles were produced by using Semi-dry method under load 78 kN/mm² and fired at 950 C°. The produced clay tiles were subjected to water absorption, efflorescence, shrinkage and compressive strength tests. The research has shown that the plasticity index depends on the mineral composition of the raw materials. The grain size analysis of raw materials, physical properties and mechanical properties of the produced tiles has shown the suitability of the used raw materials in producing class bricks of class A (first class) according to the requirements of specification of the Iraqi Standard (1993).**

***Index Terms*—Clay brick, physical properties, plasticity, X-ray diffraction.**

I. Introduction

Clay brick is made from selected clays that are molded or cut into shape and fired in oven; clay is one of the most abundant natural mineral on the earth. For brick manufacturing, clay must possess specific properties and characteristic, such as, having plasticity which permits them to be shaped or molded when mixed within sand, flux like CaO and water, and they must have sufficient wet and air-dried strength to maintain their shape after had been forming. Also, when subjected to high temperatures, the clay particles must be fuse together. Some studies were carried out on the same purpose (Lateef, 1976) evaluated the claystone sediments of Neogene age for foothill zone of Hamrin range which are mainly consistent of 20% - 50% clastic sedimentary sequence. Merza (1997) evaluated some clay deposits of Late Cretaceous-Tertiary age in the North East Iraq for manufacturing of ceramic tiles. Al-hakim (1998) studies some clay deposits of Neogene age for brick manufacturing. Merza (2002) evaluated some clay deposits from the upper part of Gercus Formation (M-Miocene), North East Iraq for brick manufacturing. Merza (2004) used the recent deposits salty clay around the Aliawa village, in south of Sulaimania city for production of glazed ceramic tiles through mixing recent deposits, Sirwan river deposits and gorge. She found that some of raw materials are suitable for manufacturing ceramic tiles for covering the walls of kitchens, public building balconies and baths. Also, (Merza and Mohyaldin, 2005) used fourteen types of clay were selected from different locations in Kurdistan region and found that some of these raw materials are suitable for manufacturing the solid and perforate bricks. Maala, et al. (2007) dealt with evaluation of the physical, chemical and mineralogical properties of mudstone sediments of Neogene age (Injana and Bai Hassan Formations) and their suitability to use them as a raw material in manufacturing of building bricks. This research focuses on raw materials which were taken from three different locations in Koisanjaq (Koya) city and have the same formation (age) and depositional environment (Buday, 1980; Buday and Jassim 1987; Al

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Jaboury and McCann, 2008). The locations of studied samples are shown in Fig. 1, which are intersected between latit. (36° 03′ 40″ – 36° 06′ 00″) North and long. (44° 38′ 00″ – 44° 42′ 00″) East.

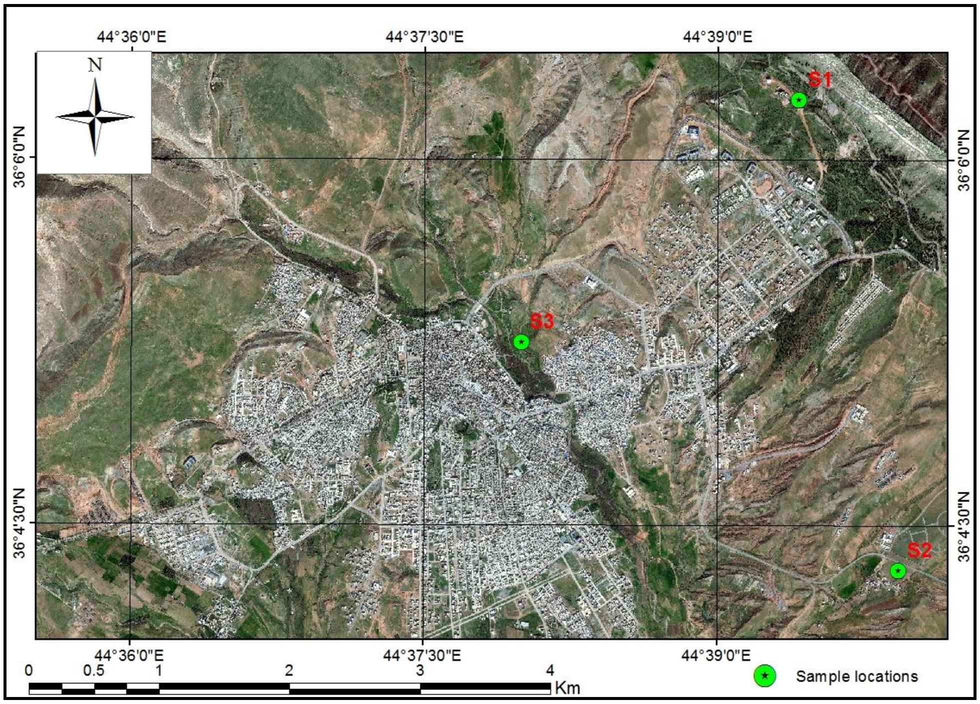

Fig. 1. Location map of Koya city, which indicates the test locations (Basir, 2013).

In order to point out the different parameters, which are conditioning the behavior of the raw materials and their suitability for clay brick industry, many tests are made on the collected raw materials such as, plastic properties and grain size distribution. Qualitative and quantitative mineral investigations were carried out by means of X-Ray Diffraction (XRD).

II. Geological Setting

The raw materials were collected from different locations in Koya city are belong to Fatha Formation. The Fatha Formation is one of the most widespread and economically has an important formation in Iraq especially in Kurdistan region. It forms continuous belt at the foot South West limb of Haibat-Sultan Mountain in Koya area and lies in Unstable Shelf, High Folded Zone with North West–South East trends parallel to Zagros belt (Buday and Jassim, 1987). It is from Middle Miocene age, comprises anhydrite, gypsum, and salt interbedded with limestone and marl (Buday, 1980).

The thickness of the formation is greatly variable. In the central parts of the basin thickness up to 900 m, was reported whereas the thickness of the formation in the studied area ranges between 60 – 200 m (Youkhana and Sisskian, 1986; Omer, 2009). The formation represents the deposit of a relatively strength sinking basin, which often had been separated from the open sea by rising ridges (Buday, 1980). The formation consist of cyclic deposits of mudstone and limestone with gypsum beds in lower cycles, mudstone, reddish brown in color are soft and highly fractured which represent the main consistent of the formation (Omer, 2009). In the studied area, the formation comprises cycles of claystone, siltstone, and sandstone with gypsum and limestone bed. Claystones, reddish brown in colour are fine to very fine grained and moderately thick bedded which represent the main constituents of the formation.

III. Methodology and Test Procedure

This research concerns the raw materials from three different locations in Koya area of Kurdistan region, Table I. Three samples were collected which are representing the clay from Fatha Formation.

In order to point out the different parameters which have the fractures of raw materials and their suitability for brick industry, as many tests have been done on the collected raw materials by laboratory of geological survey and mineral investigation, Baghdad.

TABLE I
LOCATIONS OF THE STUDIED SAMPLES

Sample No.	Formation	Locations	Coordinate (Latitude & Longitude lines)
S1	Fatha	Haibat-Sultan area	36° 06′ 15″ North & 44° 39′ 25″ East
S2	Fatha	Koya-Sulaimania road	36° 04′ 18″ North & 44° 39′ 54″ East
S3	Fatha	Central of Koya city	36° 05′ 15″ North & 44° 38′ 00″ East

The following points are based on the tests results:

- Particle size by sieve analysis based on Triangular Folk diagram, (Folk, 1974) were grouped into three fraction (sand, silt and clay), Table II, to estimate the percentage of each fraction content and evaluate the type of soil texture classification for suitability of different clay brick manufacture. Based on Triangular Folk diagram the samples (S1 and S3) are clayey silt (Mud), and the sample (S2) is Sand-Silt-Clay (Sandy mud) which may be suitable for clay brick manufacturing.
- Chemical composition analysis based on XRF (X-Ray Florescence) shows the percentage oxides content of elements such as (SiO_2, Fe_2O_3, Al_2O_3, CaO, MgO, Na_2O, K_2O and SO_3), Table III.
- The plasticity values based on Standards American Society for Testing and Materials (1996), casagrandes plasticity chart is directly related to the mineralogical composition (Bill, et al., 1992; Moulluid, 2000) which is depending on plasticity index. There are no effect of organic matter on the plasticity properties because the chemical analysis shows that the studied samples are empty from organic matter as well as the type of clay is belong to inorganic clays of low to medium plasticity (CL), Table IV.
- X–Ray Diffraction test (XRD) is now a common technique and most widely used for the identification of unknown crystalline materials (minerals). All diffraction methods are based on generation of X–ray in an X–ray tube, these X–ray are directed at the sample, and the diffracted rays are collected. The intensity of diffracted X–rays is continuously recorded as the sample and detector rotate through their respective angles. A peak in intensity occurs when the mineral contains lattice planes with d – spacing appropriate to diffract X–ray at the value of θ. Results are commonly presented as peak positions at 2θ and X–ray counts (intensity) (Brady, et al., 1995). Merza and Mohyaldin (2005) studied the Fatha Formation in Kurdistan for brick manufacture and found that it contain some of clay minerals such as (illite, smectite, kaolinite and chlorite) which are suitable for manufacturing of bricks. In the present research the X – Ray Diffraction (XRD) used to estimate the clay minerals by orientated sample curve, whereas non clay minerals estimated by bulk sample curve. XRD charts in Fig. 2, Fig. 3, Fig. 4 and Fig. 5 show that the studied samples are components of clay minerals (chlorite, illite, montmorilonite, and illite–smectite mixed layer), and non-clay minerals (quartz, calcite, muscovite and plagioclase). These tests are done by laboratory of geological survey and mineral investigation in Baghdad.

TABLE II
THE PARTICLE SIZE DISTRIBUTION PERCENTAGE OF THE STUDIED SAMPLES

Sample No.	The particle size distribution %			Type of soil
	Clay % < 0.002 mm	Silt % 0.002 – 0.063 mm	Sand % > 0.063 – 2 mm	Texture classification
S1	40	59	1	Clayey silt (Mud)
S2	31	48	21	Sandy mud (Sand-Silt Clay)
S3	30	66	4	Clayey silt (Mud)

TABLE III
CHEMICAL COMPOSITION PERCENTAGE OF THE STUDIED SAMPLES

Sample No.	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	L.O.I %	Na_2O %	K_2O %	SO_3 %
S1	45.8	5.98	17.45	10.08	2.8	11.6	0.8	2.66	< 0.07
S2	49.9	6.06	19.0	6.16	3.8	8.54	0.91	2.8	< 0.07
S3	46.72	5.26	15.5	11.76	2.7	11.87	1.0	2.34	< 0.07

TABLE IV
THE RESULT OF ATTERBERG LIMITS SAMPLES AND THE CORRESPONDING TYPE OF SOIL

Sample No.	(Liquid Limit) L.L.	(Plastic Limit) P.L.	(Plasticity Index) P.I.	Type of soil
				Grade symbol
S1	38.35	22.79	15.56	CL
S2	25.48	16.99	8.48	CL
S3	22.34	15.65	6.70	CL

- Methodology for preparing the molded samples is semi – dry method of forming three tiles under press load 78 kN/mm² were adapted and fired at a temperature of 950 C°, the studying of physical and mechanical properties of the samples include the following:
  - Compressive strength (three molded samples used for repeating the test).
  - Linear shrinkage (very little affected).

- Volume shrinkage (very little affected).
- Water absorption.
- Efflorescence (none).

The results of the above properties were compared with the requirements of specification of the Iraqi Standard, 1993) as shown in Tables V and VI.

TABLE V
SPECIFICATION OF THE IRAQI STANDARD (1993) FOR CLAY BRICK MANUFACTURING

Efflorescence	High limit of water absorption %		Low limit of compressive strength Kg/cm²		Classes
	(for one brick)	Average water absorption (for ten brick)	Compressive strength (for one brick)	Average compressive strength (for ten brick)	
Light	22%	20%	160	180	A
Medium	26%	24%	110	130	B
-----	28%	26%	70	90	C

TABLE VI
THE RESULTS OF SOME BRICK PHYSICAL AND MECHANICAL PROPERTIES OF THE STUDIED SAMPLES

Sample No.	Brick dimensions (cm)			Linear shrinkage %	Volume shrinkage %	Physical properties		Mechanical properties	Class
	Length	Width	Height			Water absorption %	Efflorescence	Compressive strength Kg/cm²	
S1	7.38	3.9	2.58	0.5	0.6	20	None	407	A
S2	7.33	3.88	2.56	0.5	0.4	18	None	376	A
S3	7.24	3.77	2.48	0.5	2.5	19	None	429	A

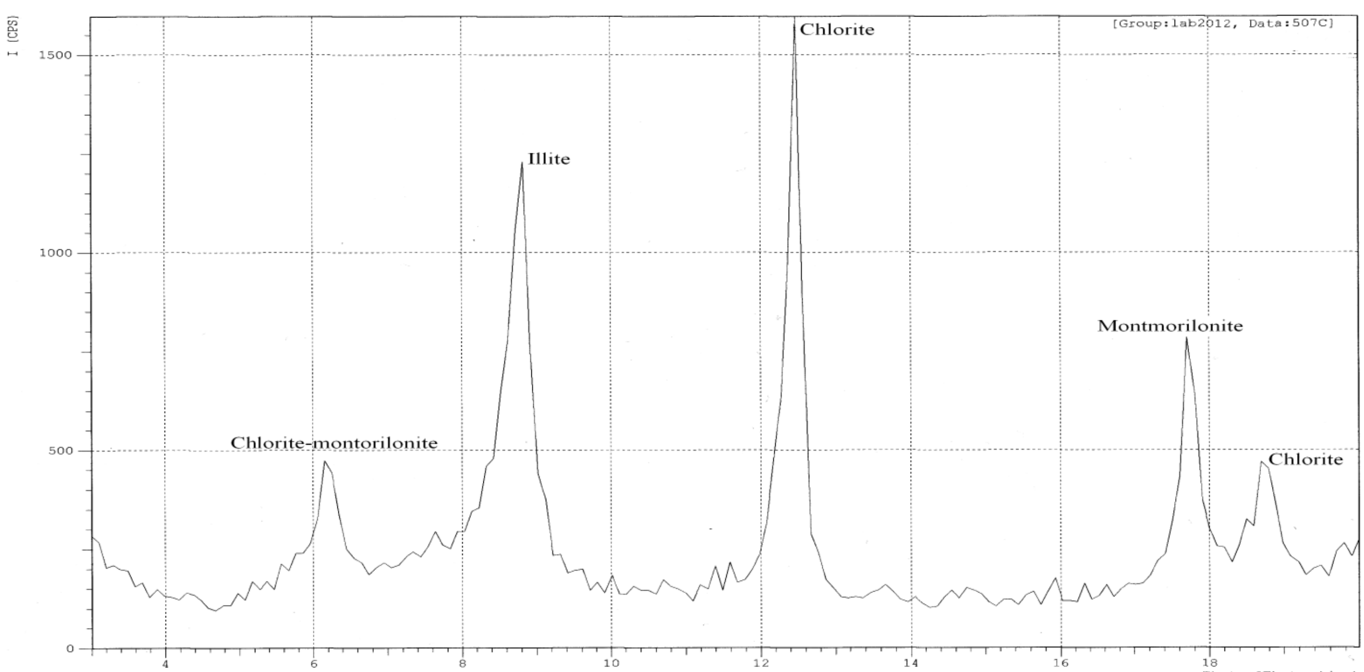

Fig. 2. XRD chart for the Sample No. S1 (Oriented sample)

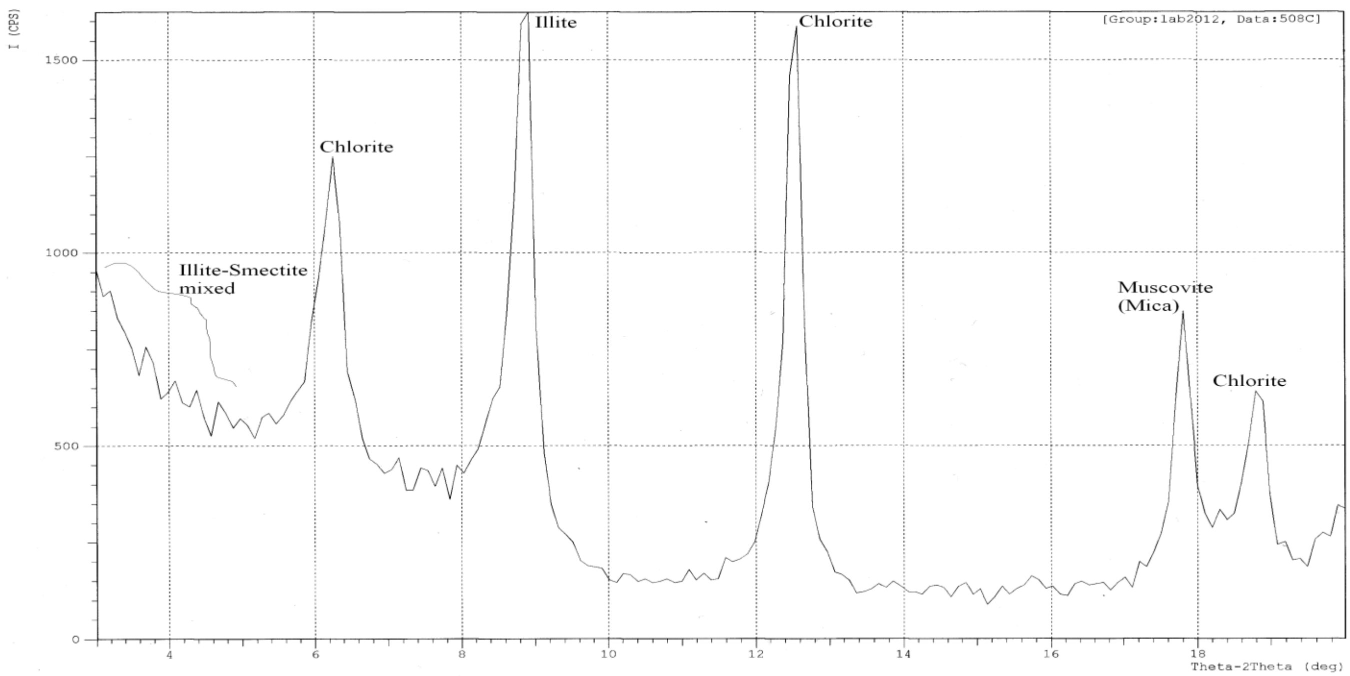

Fig. 3. XRD chart for the Sample No. S2 (Oriented sample)

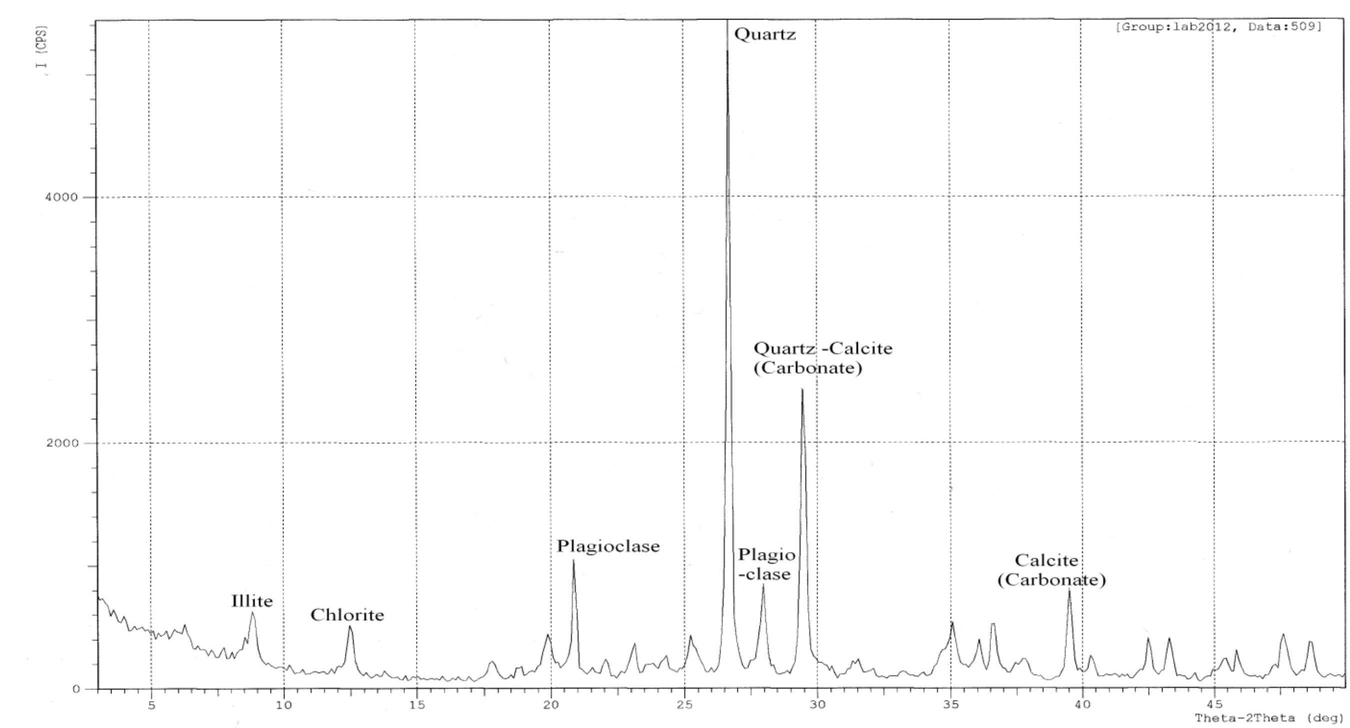

Fig. 4. XRD chart for the Sample No. S3 (Bulk sample)

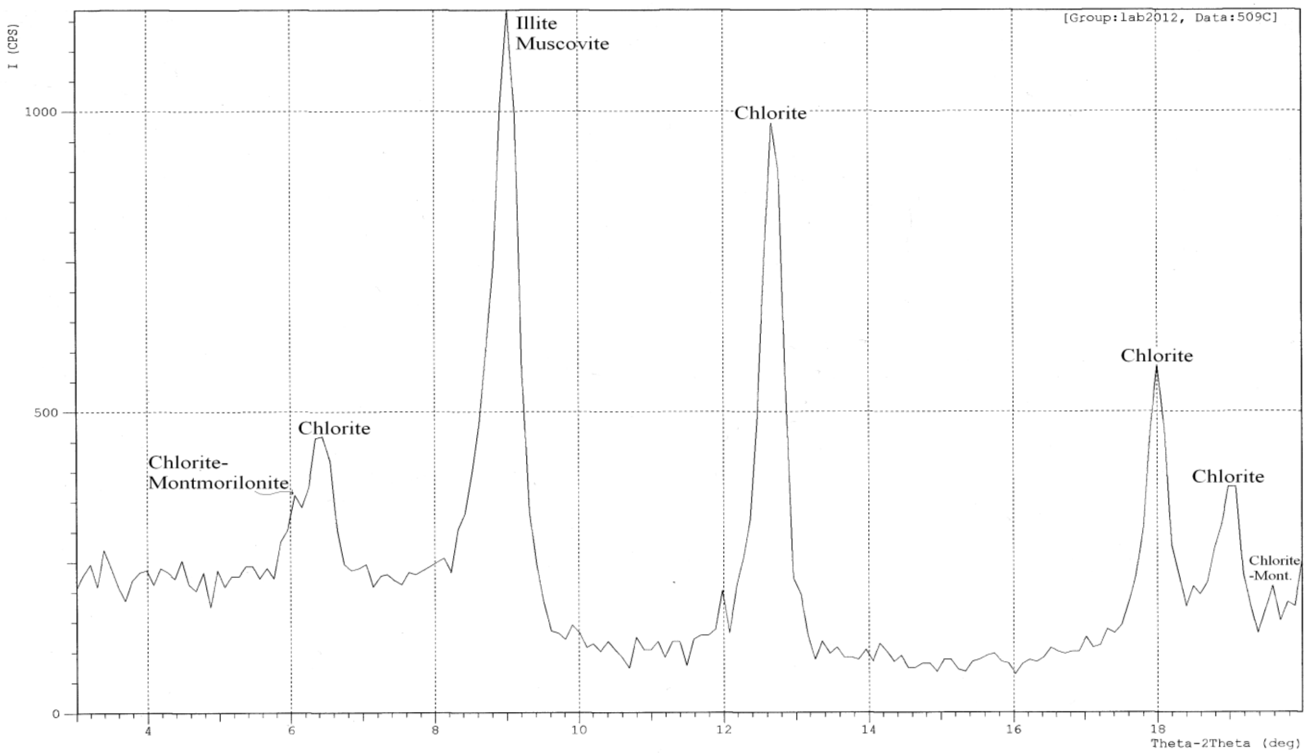

Fig. 5. XRD chart for the Sample No. S3a (Oriented sample)

IV. Results and Discussion

- The result of particle size analysis in Table II shows that the dominant percentage of silt fraction ranging 48% – 66%, the percentage of clay 30% – 40% and sand 1% – 21% in the three studied samples. Based on the Triangular Folk Diagram (Folk, 1974) which used to classify the clastic sediments, the studied samples consist of clayey silt (mud), and sand-silt-clay (sandy mud), these constituents and CaO about 10% have little amount of gypsum which are unaffected on the cohesive of the clay brick if they are occur in the chemical composition of the clays and cause failure of the brick (Allen and Lano, 2009), to compare between these results with the clay bricks of Iraqi Standard (1993), Table V, which are consist of the same fractions (silt-clay-sand), these indicators considered as good evidence for manufacture of clay brick from the studied samples.
- Punmia, Jain and Jain (2003) stated that normally clay brick contains the following ingredients:

a) Silica (sand) 50% – 60% by weight.
b) Alumina (clay) 20% – 30% by weight.
c) Lime 2% – 5% by weight.
d) Iron oxides 5% – 6%, not greater than 7% by weight.
e) Magnetite- less than 1% by weight.

The result of chemical composition in Table III shows that the main percentage of SiO_2 is not be changed, mostly in the studied samples ranging from 45.8% – 49.9%, Al_2O_3 15.5% – 19%, as well as different percentage of (Fe_2O_3, CaO, MgO, K_2O, Na_2O and SO_3). These constituents of oxides elements are directly proportional with the clay minerals' composition as well as they considered melting resistance materials. So from this discussion may detect that the studied samples are favorable for brick industry according to Iraqi Standard (1993), Table V.

- Plasticity index (PI) is a measure of plasticity of soil. The (PI) is the size of the range of water content where the soil exhibits plastic properties, and shows the difference between the liquid limit (LL) and the plastic limit (i.e PI=LL–PL). According to the Standards American Society for Testing and Materials (1996) the United State (US) soil classification is depending on the (PI):
  - 0 – Non plastic
  - (1 – 5) – Slightly plastic
  - (5 – 10) – Low plastic
  - (10 – 20) – Medium plastic
  - (20 – 40) – High plastic
  - > 40 very high plasticity

From the plasticity values the studied sample (S1) (PI = 15.56) is belong to medium plasticity inorganic clay (CL), but samples (S2 & S3) (PI = 6.70 – 8.48) are belong to low plasticity inorganic clay (CL) according to Standards American Society for Testing and Materials

(1996) and Casagrandes plasticity chart (Casagrande, 1932).

Based on plasticity values in Table IV, range between (6.70 – 15.56) pointed out that this percentage is less proportional with the clay minerals water content such as (kaolinite, illite, chlorite), because molecular nature of these clay minerals have not ability to drawn the water (i.e., they does not absorb water, does not expand where they are contact with water) whereas montmorilonite derived by weathering of volcanic ash, it can expand by several times its original volume when it come in contact with water (Klein, 2002). So the result of (PI) document that the studied samples are suitable for clay brick industry.

- The results of some physical and mechanical properties of producing clay brick characterized by general appearance which is pointed out to the red and reddish brown colour with homogeneous and regular dimension, straight edges with right angles, planar surface without fractures or cracks, efflorescence is not occurs on the clay brick surface (i.e., free from the salty deposits). These parameters lead to good evidence that the type of clay brick is belong to class (A) because of smooth, rectangular surface with parallels sharp and straight edges, also free from cracks and stones with uniform texture (Punmia, 1993). According to specifications of the Iraqi Standard (1993) the studied samples are belong to class (A) due to high compressive strength range from 376 – 429 Kg/cm^2, water absorption 18% – 20% with linear shrinkage 0.5% and volume shrinkage 0.4% – 2.5%, compressive strength of clay brick is positively associated with the percentage of clay minerals mainly with the concentration of Al, Si, but the water absorption (term of porosity) is related with carbonate and evaporate minerals (Gypsum). Al-Bassam (2004) stated that the surface area of brick increased with the released of CO_2 from carbonate and H_2O from gypsum after drying which caused to form high porosity (voids) on the brick surfaces but the studied samples indicate that have high compressive strength with low percentage of water absorption.
- Maala, et al. (2001) used the ratio SiO_2/CaO percentage that if the percentage is equal to 2:1, it is considered to be suitable for brick manufacturing, but if it is less than this percentage, it does not become suitable for brick manufacture. In this study there are very little amount of CaO content nearly 10% that means the silicate clay minerals are dominant content in the studied samples, because the ratio of SiO_2/CaO percentage is equal to 5:1.

In general, when the temperature increased the water absorption capacity and volume decreased, the porosity diminished, the compressive strength increased significantly (Merza and Mohyaldin, 2005). The method which is used by laboratory of geological survey and mineral investigation in the presence research is semi – dry method, the tiles fired at 950 C° and the soaking time was only one hour.

According to the British Standard (1985) for the efflorescence test, the samples may be classified as no efflorescence, i.e, the surface area not covered by salt content (Punmia, 1993), this phenomena was not occurred in the studied samples, i.e., the studied samples are none efflorescence according to the laboratory tests as shown in Table VI. As a result, all these physical and mechanical properties are directly proportional with the suitability of studied samples for brick manufacturing.

V. Conclusion

Based on the results of this study the following conclusions have been reached out:

Firstly; the plasticity values show that sample no. (S1) is medium plastic, samples no. (S2 and S3) are low plastic, clays must have plasticity, which permits them to be shaped or molded when mixed with water, and they must have sufficient wet and air dried tensile strength to maintain their shape after forming. Also, when subjected to rising temperature, the clay particles must fuse together (i.e., the plasticity values show that the sample no. S2 and S3) have low plasticity range between 6.7 – 8.48, these values permit to made shaped tiles according to (Maala, et al., 2007).

Secondly; X-Ray Diffraction show that the samples are constitute of clay minerals (such as illite, chlorite, kaolinite, illite – smectite mixed layer) and non-clay minerals (quartz, calcite and plagioclase).

Thirdly; the physical and mechanical properties that most concern with the clay brick are;

- The type of clay brick class is (A) due to measure of physical and mechanical properties.
- Efflorescence (salt cover) has very little appearance on the clay brick surface.
- Clay brick affected by low volume and linear shrinkage during both drying and firing with higher temperature at 950 C°.

Fourthly; it was concluded that the raw materials taken from Fatha Formation in Koya city are suitable for producing high quality clay brick.

References

Al Jaboury, A. I. and McCann, T., 2008. The Middle Miocene Fatha Formation. *Geo Arabia (Manama)*, 13(3), pp.141-174.

Al-Bassam, K.S., 2004. *Assessment of physical and chemical properties for raw material used in bricks manufacture*. Baghdad: Publication of GEOSURV.

Al-hakim, F.A., 1998. *Assessment of some clay from Neogene for ceramic purposes-N Iraq.* M. Sc. Thesis, University of Baghdad.

Allen, E. and Lano, J., 2009. *Fundamentals of building and construction: Materials & Methods*. 5th ed. Hoboken: John Willey & Sons.

Basir Remote Sensing Insitute, 2013. *Satellite GeoEye-1*, 1:1000000. Available at <http://www.satimagingcorp.com/satellite-sensors/geoeye-1/> [Accessed 13 February 2013].

Bill, F. , Dondi, M., Fabbri, B, and Morandi, N., 1992. Carbonate clays for the production of porous ceramic tiles by fast single firing. *Geological Carpathica International Clay Journal*, 1(2), pp.91-95.

Brady, J.B., Newton, R.M., and Boardman, S.J., 1995. New Uses for Powder X-ray Diffraction Experiments in the Undergraduate Curriculum. *Journal of Geological Education*, 43(5), pp.466-470.

British Standards Institution, 1985. BS 3921: 1985 *British Standard specification for clay bricks*. London: BSI.

Buday, T., 1980. *The Regional geology of Iraq, vol. 1: stratigraphy and paleontology*. Baghdad: Publication of GEOSURV.

Buday, T. and Jassim, S., 1987. *The Regional geology of Iraq, vol. 2: Tectonism, Magmatism and Metamorphism*. Baghdad: Publication of GEOSURV.

Casagrande, A., 1932. Research on the atterberg limits of soils. *Public Roads*, 13(8), pp.121-136.

Folk, R., 1974. *Petrology of sedimentary industrial rocks and minerals*. Texas: Hemphill Publ. Co.

Iraqi Standards, 1993. IS No.25: 1993 *Clay building bricks*. Baghdad, IS.

Klein, C., 2002. *The manual of mineral science*, 22nd ed. New York: John Wiley & Sons.

Lateef, A., 1976. *Regional geological mapping of Hamrin range*. Baghdad: Publication of GEOSURV.

Maala, K., Jabo, B., Al-Saad, N., Lafta, A., and Fayath, K., 2001. *Assessment of quality and quantity of stratified clay soil for manufacture of clay brick in South of Mosul.* Baghdad: Publication of GEOSURV.

Maala, K., Sood, Q., Khames, D., Jabo, B., Al-Saade, N. and Khadhum, M., 2007. Laboratory assessment for utilization of Neogene mudstones in manufacturing of building bricks. *Iraqi Bulletin of Geology and Mining*, 3(2), pp.1-15.

Merza, T.A. and Mohyaadldin, M., 2005. Manufacture of brick tiles from local raw materials, N & NE Iraq. *Zankoy Sulaimani Journal*, 8(1/A), pp.31-45.

Merza, T.A., 1997. *Assessment of some clay from U. Cretaceous and Tertiary for ceramic purposes-NE Iraq*. M. Sc., University of Baghdad.

Merza, T.A., 2002. Assessment of some clay from Gercus Formation, M. Eocene, for brick manufacture, Sulaimani area, NE Iraq. *Zankoy Sulaimani Journal*, 5(1), pp. 57-67.

Merza, T.A., 2004. The possibility of production of glazed ceramic tiles from the recent deposits, Sulaimani region, NE Iraq. *KAJ Journal*, 3(1), pp.23-32.

Moulluid, Y., 2000. *Sub-baked stabilized soil blocks for building*. M. Sc., University of Sallahadeen.

Omer, H., 2009. *Primary geotechnical assessment of Haibat -Sultan area and its suitability for proposed tunnel construction*, M. Sc., Koya University.

Punmia, B., 1993. *Building construction*, 5th ed. New Delhi: Laxami Publications (P) Ltd.

Punmia, B., Jain K. and Jain Kr., 2003. *Basic civil engineering*. New Delhi: Laxami Publications.

Standards American Society for Testing and Materials, 1996. D4318: 1996 *Standard test method for liquid limits, plasticity index of soils*. America: ASTM.

Youkhana, R. and Sissakian,V., 1986. Stratigraphy of Shaqlawa-Koisanjaq area. *Journal of the Geological Society of Iraq*, 19(3), pp.137-154.

Static Analysis of Steel Fiber Concrete Beam With Heterosis Finite Elements

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***Abstract*— Steel fiber is considered as the most commonly used constructional fibers in concrete structures. The formulation of new nonlinearities to predict the static performance of steel fiber concrete composite structures is considered essential. Present study is devoted to investigate the efficiency of utilizing heterosis finite elements analysis in static analysis of steel fibrous beams. New and simple material nonlinearities are proposed and used in the formulation of these elements. A computer program coded in FORTRAN was developed to perform current finite element static analysis with considering four cases of elements stiffness matrix determination. The results are compared with the experimental data available in literature in terms of central deflections, strains, and failure form, good agreement was found. Suitable outcomes have been observed in present static analysis with using of tangential stiffness matrix and stiffness matrix in second iteration of the load increment.**

***Index Terms*—Hetrosis elements, mechanics of concrete structures, static analysis.**

I. Introduction

It is reality that, except of chemical and mineral admixtures, the mechanical properties of concrete are enhanced with introducing of different ingredients to the fresh concrete as steel fibers, carbon fibers, glass fibers etc. Recently, the using of steel fiber reinforced concrete SFRC is increased in real-life applications. SFRC is widely used in many constructions such as tunnels, beams and slabs, domes, reinforced concrete building to resist seismic actions and marine structures. The employing of special sizes of steel fibers in concrete material improves crack performance which produces a ductile concrete with good absorption capacity (Ocean Heidelberg Cement Group, 1999). The ductile analysis and design of reinforced concrete beams are usually considered in flexural problems.

Many experimental and numerical works have been launched to investigate the performance of SFRC beams under the effect of static loadings. The effect of steel fibers on beam flexural cracking, toughness of SFRC beams, shear resistance, crack width, static load capacity and compressive strength and tensile strength have been studied in many references (Dupont and Vandewalle, 2002; Gopalaratnam, et al., 1991; Paine et al., 2002; Ganesan and Shivananda, 2002; Alavizadeh-Farhang, 1998; Hartman, 1999; Compione and Mangiavillano, 2008; Cucchiara, et al., 2004).

Numerical procedures have been used to study the static behavior of SFRC beams by many authors (Bangash, 1989; Hemmaty, 1998; ANSYS, 2003; Huyse, et al., 1994).

Due to the fact that many shapes of steel fibers are available to use in concrete structures, the need for new and simple nonlinear relationships for mechanical properties of SFRC material is considered useful. Therefore, present endeavor is concentrated in developing new finite element procedure for static analysis of SFRC beams with introducing new simple nonlinear material formulations with heterosis elements.

II. Methodology

Current static analysis comprises of proposing new and simple nonlinearities and using them in producing a novel developed finite element procedure for concrete beam analysis with using heterosis nine-noded elements.

A. Heterosis Elements

In present investigation, the heterosis shell elements are used. These elements are characterized with three displacements and two rotations at each nodal point. The local coordinates (α, β) of each node are illustrated in Fig. 1.

The Cartesian coordinates (x, y and z) of any point over each element can be determined by using the nodal coordinate values (x_i, y_i and z_i) and nodal shape function N_i as follows:

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix} = \sum_{i=1}^{n} N_i(\alpha,\beta).\begin{Bmatrix} x_i \\ y_i \\ z_i \end{Bmatrix} \quad (1)$$

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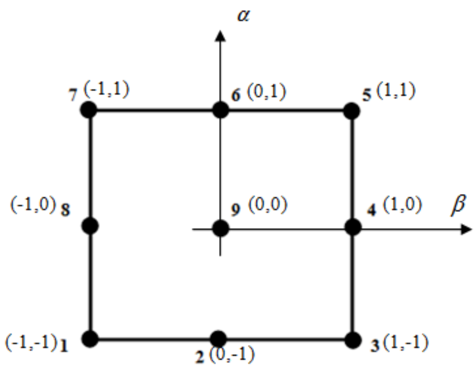

Fig. 1. Local coordinates of heterosis element.

In the similar manner, the displacement at any location (u, v, w) over the element can be estimated using the nodal displacements of u_i, v_i and w_i in x, y and z directions respectively of each element as hereunder:

$$\begin{Bmatrix} u \\ v \\ w \end{Bmatrix} = \sum_{i=1}^{n} N_i \cdot \begin{Bmatrix} u_i \\ v_i \\ w_i \end{Bmatrix} \quad (2)$$

The displacements are determined at each nodal point, while the strains are found at each Gauss point. The element is separated into concrete and reinforcement steel bar plates through the beam depth. The Gauss points are located over each plate as in Fig. 2. The strain and stress values are determined at each Gauss point.

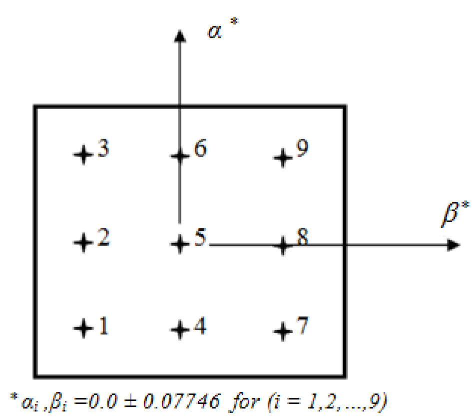

Fig. 2. Location of nine Gauss points of heterosis element.

The strain vector is given as (Al-Ta'an and Ezzadeen, 1995):

$$\{\varepsilon\} = [B]\{\delta\} \quad (3)$$

where; $\{\varepsilon\}$ is the nodal strain vector, $\{\delta\}$ is the nodal displacement vector and $[B]$ is the strain - displacement matrix which separated into two parts namely bending and shear displacement - strain matrices which are given as follows:

$$[B]_b = [B^1, B^2, B^3, ..., B^9] \quad (4)$$

$$B^i = \begin{bmatrix} 0 & \frac{\partial P_i}{\partial x} & 0 \\ 0 & 0 & \frac{\partial P_i}{\partial y} \\ 0 & \frac{\partial P_i}{\partial y} & \frac{\partial P_i}{\partial x} \end{bmatrix} \quad \text{for } 1 \le i \le 8 \quad (5)$$

And for node 9, B^i will be as follows:

$$B^9 = \begin{bmatrix} \frac{\partial P_9}{\partial x} & 0 \\ 0 & \frac{\partial P_9}{\partial y} \\ \frac{\partial P_9}{\partial y} & \frac{\partial P_9}{\partial x} \end{bmatrix} \quad (6)$$

$$[B]_s = [B_s^1, B_s^2, ..., B_s^9] \quad (7)$$

$$B_s^i = \begin{bmatrix} \frac{\partial N_i}{\partial x} & -P_i & 0 \\ \frac{\partial N_i}{\partial y} & 0 & -P_i \end{bmatrix} \quad \text{for } 1 \le i \le 8 \quad (8)$$

and

$$B_s^9 = \begin{bmatrix} -P_9 & 0 \\ 0 & P_9 \end{bmatrix} \quad \text{for node 9} \quad (9)$$

Where;
B^i_b is bending strain – displacement component for nodes i = 1 to 8, B^9_b is bending strain – displacement component for node i = 9, P_i is Lagrangian shape function, B^i_s is shear strain – displacement component for nodes i = 1 to 8 and B^9_s is shear strain – displacement component for node i = 9.

Consequently, the stiffness matrix [S] of each element is divided into two groups namely element stiffness matrix for bending [S_b] and element stiffness matrix for shear [S_s] as follows:

$$[S] = [S_b] + [S_s] \quad (10)$$

B. *Present Nonlinear Relationships of SFRC Behavior*

The introducing of steel fibers in concrete will lead to produce non-homogenous material which characterized by different behaviors under tension and compression actions. Thus, in order to simulate the performance of concrete material, suitable nonlinearities are required to represent the concrete behavior under compression and tension forces in the finite element procedure (Abdul-Razzak and Ali, 2011a; Abdul-Razzak and Ali, 2011b).

Depending on theories of elasticity and plasticity, the compression behavior of concrete can be considered in finite element analysis. To simulate this compression behavior, Madrid equation was employed to represent the yield surface growing during the compression loading as follows (Al-Ta'an and Ezzadeen, 1995):

$$\sigma_c = -f_{co}\frac{\varepsilon_c}{\varepsilon_{cs}}\left[\frac{\varepsilon_c}{\varepsilon_{cs}} - 2\right] \tag{11}$$

Where;
σ_c is the compression stress,
ε_c is the compression strain,
ε_{cs} and is the strain value corresponding to concrete compression strength,
f_{co} is the compression strength of concrete.

The modulus of elasticity of concrete Ec is given by the following formula:

$$E_c = \frac{2 f_{co}}{\varepsilon_{cs}} \tag{12}$$

Therefore, (1) can be given as follows:

$$\sigma_c = E_c\varepsilon_c - \frac{E_c\varepsilon_c^2}{2\varepsilon_c} \tag{13}$$

The derivation of (13) with respect to ε_{cs} is named by hardening parameter Hp which is given as:

$$Hp = \left(\sqrt{\frac{\varepsilon_{cs}}{\varepsilon_{pl}}} - 1\right) \tag{14}$$

where;

$$\varepsilon_{pl} = \varepsilon_c - \frac{\sigma_c}{E_c} \tag{15}$$

Hp is used in representing the growing of compression stress curve of SFRC.

In the case of steel fiber concrete material under two perpendicular compression forces, the concrete strength f_{c2} is increased by a value of magnification factor ir as follows:

$$f_{c2} = ir.f_{co} \tag{16}$$

where $ir \geq 1.0$

Depending on numerous experimental data in literature (Hsu and Hsu, 1994; Ashour, et al., 2000; Kurihara, et al., 2000; Bayramov, et al., 2004; Song and Hwang, 2004; Lim and Nawy, 2005; Koksal, et al., 2008; Thomas and Ramaswamy, 2007; Lin, et al., 2008; Bencardino, et al., 2010), the formula for magnification factor ir is proposed with using of nonlinear regression analysis of these experimental data in SPSS 17 program. Two parameters are considered in formulating ir equation namely fiber content Co and fiber aspect ratio A_f as follows:

$$ir = 1.997a \tag{17}$$

where

$$a = \sqrt{Co.Af} \tag{18}$$

$$Af = \frac{fiber \quad length}{fiber \quad equivalent \quad diameter} \tag{19}$$

An expression is proposed also for ε_{cs} as hereunder:

$$\varepsilon_{cs} = 0.004628a \tag{20}$$

To predict the crushing at each Gauss point, the maximum compression strain value is represented in mathematical formulation depending on experimental data in aforementioned references as follows:

$$\varepsilon_{crush} = 0.009631a \tag{21}$$

In the current work, tension strain magnitude ε_{ts} corresponding to the tensile strength of SFRC material is used to predict the SFRC behavior under tension forces. The best formulation of this strain is proposed based on the nonlinear regression rule as follows:

$$\varepsilon_{ts} = 0.0002698a \tag{22}$$

The cracks are supposed to be formed at Gauss points, when the tension strain is reached the strain value ε_{ts}.

After occurring of cracks at Gauss point, the Poisson's ratio and modulus of elasticity are considered null in the perpendicular direction to the cracks. Then the reduced cracked modulus is employed to represent the aggregate interlock. The cracked modulus S_{cr} is determined according to the regression analysis of previously mentioned references (Hsu and Hsu, 1994; Ashour, et al., 2000; Kurihara, et al., 2000; Bayramov et al., 2004; Song and Hwang, 2004; Lim and Nawy, 2005; Koksal, et al., 2008; Thomas and Ramaswamy, 2007; Lin, et al., 2008; Bencardino, et al., 2010) as follows:

$$S_{cr} = 5.533a \tag{23}$$

Based on the present proposed strain value of ε_{ts}, two nonlinear equations given by Hasan (2002) are modified as hereunder:

$$\sigma_{tb} = f_{te}\left[1-\left((1-\frac{\varepsilon_{tb}}{\varepsilon_{ts}})\right)^{E_i.\frac{\varepsilon_{ts}}{f_{te}}}\right] \quad (24)$$

$$\sigma_{ta} = f_{te}.e^{-f_{te}.F.(\frac{\varepsilon_{ta}}{\varepsilon_{ts}}-1)^G} \quad (25)$$

Where;
σ_{tb} tensile stress before crack,
σ_{ta} tensile stress after crack,
Ei initial modulus of elasticity of SFRC based on the experimental tensile strength values used by Hasan (2002),
f_{te} concrete tensile strength,
ε_{tb} tensile strain before crack,
ε_{ta} tensile strain after crack.

$$F = 0.66875 - 0.48842\left(Co.\frac{fiber \quad length}{fiber \quad diameter}\right) + 0.1125\left(Co.\frac{fiber \quad length}{fiber \quad diameter}\right)^2 \quad (26)$$

$$G = 6.26513\left(\frac{fiber \quad length}{Co.fiber \quad diameter}\right)^{-0.50327} \quad (27)$$

These proposed nonlinear formulations can be given graphically with using common values of factor *a* as depicted in Fig. 3. Excellent correlation coefficient of 95% was found for the proposed values given in Fig. 3.

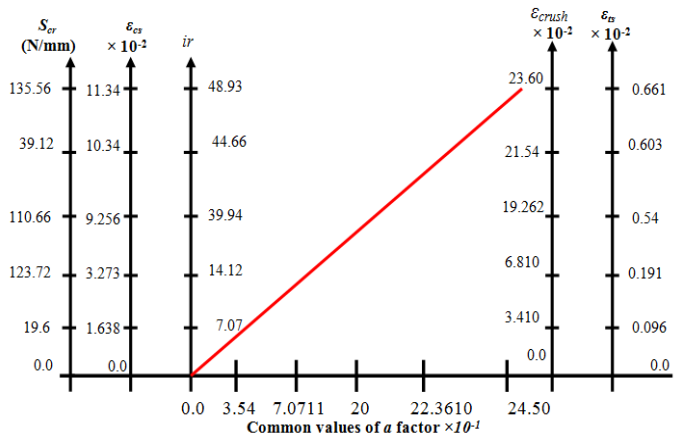

Fig. 3. Common values of proposed nonlinearities.

According to the comparison of the proposed nonlinearities with the experimental data given in Table I, good agreement was obtained.

TABLE I
COMPARISON OF THE PROPOSED NONLINEARITIES WITH SOME EXPERIMENTAL DATA

Proposed/ Experimental value	Proposed value	Experimental value	Aspect ratio	Fiber content %	Proposed model
ir	1.0012	1.18144	1.18	70.00	0.50
	1.3900	1.67	1.20	70.00	1.00
S_{cr}	0.8115	4.95	6.10	80.00	1.00
	0.8684	4.95	5.70	80.00	1.00
	1.2700	4.95	3.90	80.00	1.00
	0.9722	7.00	7.20	80.00	2.00
	1.0938	7.00	6.40	80.00	2.00
ε_{cs}	0.5333	0.0016	0.0030	55.046	0.50
	0.7188	0.0023	0.0032	55.046	1.00
	0.7800	0.0027	0.0035	55.046	1.50
ε_{crush}	0.8556	0.0077	0.0090	40.00	1.60
	0.9636	0.0106	0.0110	40.00	3.00
ε_{ts}	0.9308	0.0001	0.0001	40.00	0.50
	0.9500	0.0001	0.0001	40.00	1.00
	1.00	0.0002	0.0002	40.00	1.50

C. Nonlinear Finite Element Static Analysis

Nonlinear behavior is usually used in the analysis of concrete structures due to the cracking of concrete or yielding of steel bars. In the present study, Newton-Raphson approach was used. In this approach, four cases of stiffness matrix determination have been considered, namely, using of initial stiffness matrix for all load increments, considering tangential stiffness method in static analysis, calculating of stiffness matrix in the first iteration of each load increment and determining of stiffness matrix in the second iteration of each load increment. The convergence of the static analysis solution during each load increment is checked with using tolerance of 0.008. Thus the closeness of analysis outputs to the actual results is satisfied as shown in Fig. 4.

Computer program coded in FORTRAN language was prepared to investigate the static analysis of concrete SFRC beam. Present proposed nonlinear novel formulations were used in this program. The flow chart of this analytical procedure is depicted in Fig. 5.

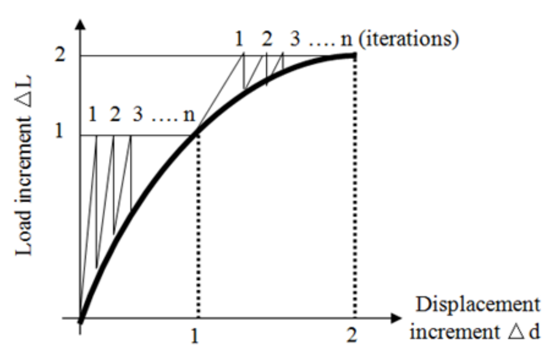

Fig. 4. Newton-Raphson concept.

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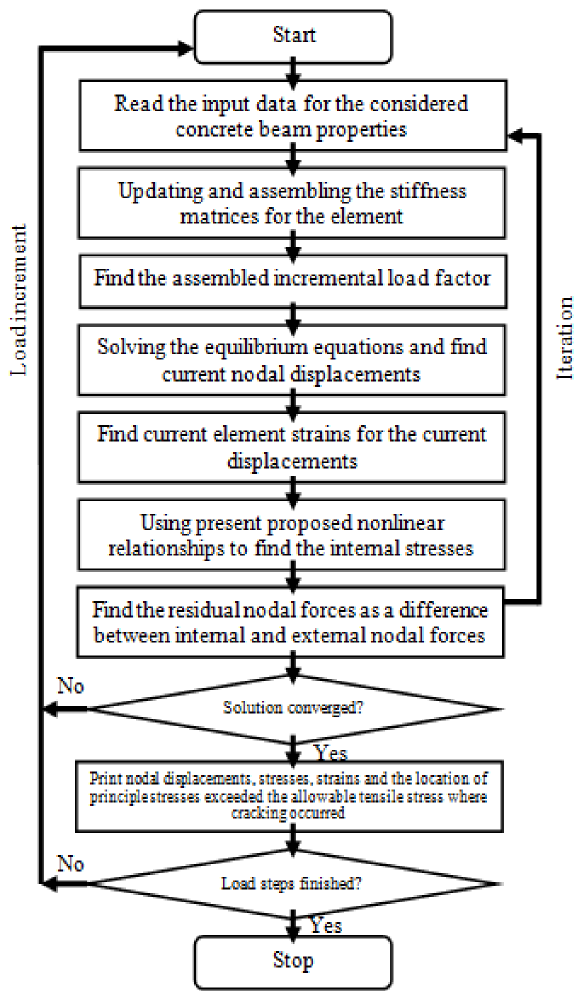

Fig. 5. Outline of present computer program for static analysis of SFRC beam

III. Numerical Applications

Many SFRC beams contain various steel fiber shapes have been considered in the static analysis with using current nonlinear finite element procedure. The validity of the proposed nonlinear models in static analysis outcomes of SFRC beams has been taken into account.

A. *SFRC Beam with Square Cross Section and Subjected to a Point Load*

A SFRC beam with the geometry, reinforcement and loading given in Fig. 6 was tested by Compione and Mangiavillano (2008). Hooked steel fibers have been used in the preparing of fibrous concrete beam. The characteristics of the beam and the used steel fibers are listed in Table II. Three different effective thicknesses 5mm, 15mm and 25mm for concrete cover were adopted in the flexural test. This beam was considered in present static analysis procedure to check the validity of the proposed nonlinearities and consequently the developed heterosis finite element analysis. Half of the beam was selected in the analysis due to the symmetry of the beam geometry and loading. Two heterosis elements (Fig. 7) with ten concrete strata and two steel bar layers were used to model half of the beam. Four cases of stiffness matrix determinations given in section II-B are used in beam analysis. The outcomes are represented in terms of load-central deflection curves, ultimate loads and failure shape of the beam.

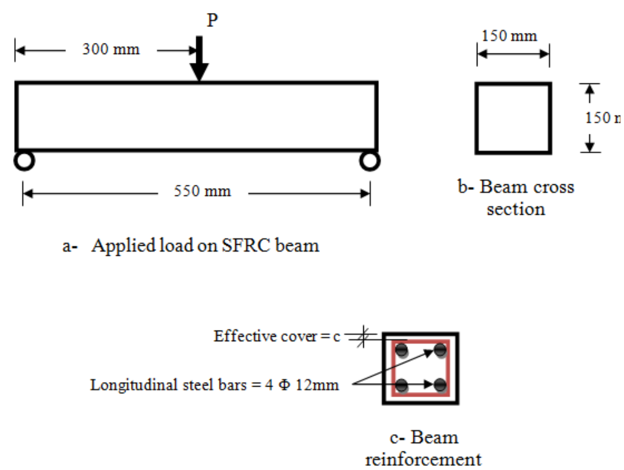

Fig. 6. SFRC beam 1.

TABLE II
PROPERTIES OF REINFORCED CONCRETE USED FOR SFRC BEAM 1

Compressive strength MPa	36.19
Tensile strength MPa	3.31
Yield stress of steel bars MPa	467
Modulus of Elasticity of steel bars MPa	206000
Fiber length mm	30
Fiber diameter mm	0.5
Fiber aspect ratio	60
Steel fiber content in concrete %	1

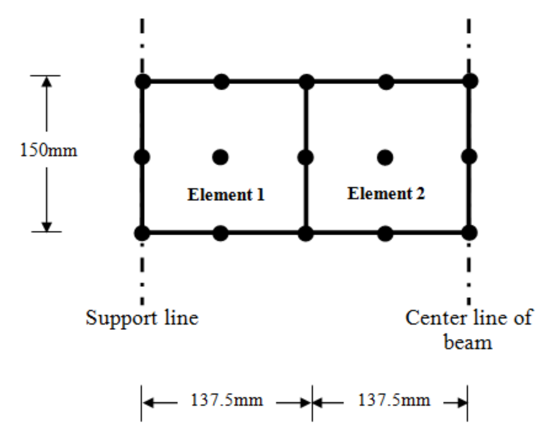

Fig. 7. Finite element mesh of SFRC beam 1.

Present load-displacement curves are compared with the experimental outputs given by Compione and Mangiavillano (2008) as illustrated in Figs. 8–10, good correlation was observed in using stiffness case 2 compared to other cases. This has been proved by determining the average value of ratios of the determined displacement (for each stiffness case) and measured experimental displacement at the ultimate load. In the other words, the ratio which is close to one is the best case.

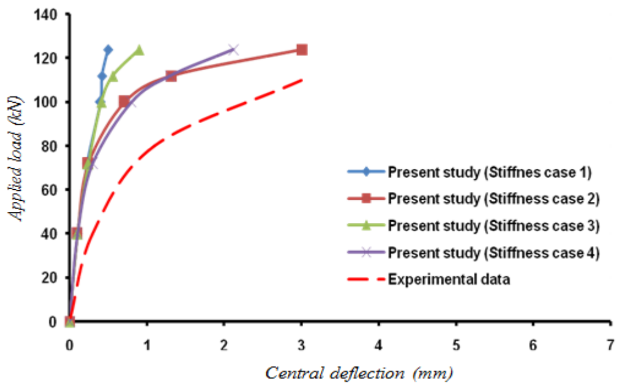

Fig. 8. Load-deflection relationship for SFRC beam 1 with c = 5mm.

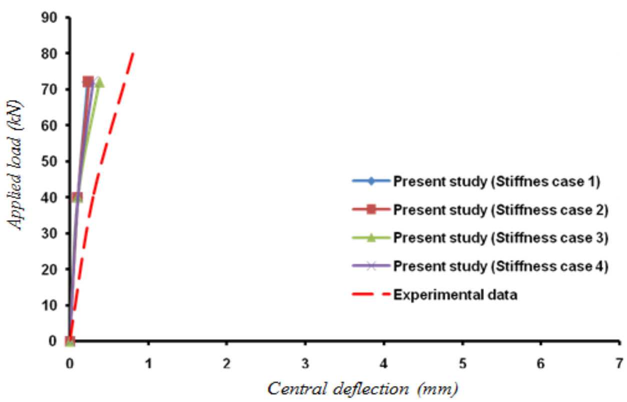

Fig. 9. Load-deflection relationship for SFRC beam 1 with c=15mm.

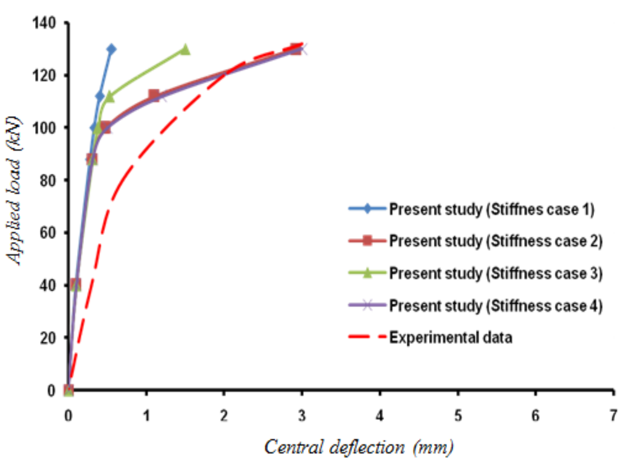

Fig. 10. Load-deflection curve for SFRC beam 1 with c=25mm.

So, according to Table III and Fig. 11, the employment of case 2 gives good results and the calculated displacement value is about 80% of actual magnitude with consideration of three concrete cover values of 5mm, 15mm and 25mm.

TABLE III
DISPLACEMENT ACCOMPANIED WITH THE ULTIMATE LOAD

Effective cover mm	Stiffness case	Displacement (Present study)	Displacement (Experimental result)	Analytical results/Experimental outcomes
5	1	0.5524	3	0.1841
	2	2.924		0.9750
	3	1.50		0.50
	4	3.00		1.00
15	1	0.2243	0.80	0.2804
	2	0.24		0.30
	3	0.375		0.47
	4	0.30		0.3750
25	1	0.50	3	0.17
	2	3.011		1.004
	3	0.90		0.30
	4	2.12		0.71

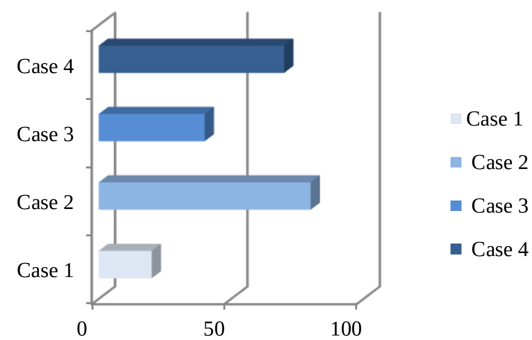

Fig. 11. Compatibility between numerical and experimental outputs for beam 1.

The failure pattern under static loading was also estimated by using present finite element formulations with stiffness case 2 for many load steps as depicted in Fig. 12. With performing comparison between the numerical cracking pattern and actual beam failure from the test (Fig. 13), it was observed that the cracks are concentrated in the region close to the mid-span of the beam which agree with the experimental failure mode.

B. SFRC Beam with Rectangular Cross Section and Subjected to a Point Load

A simply supported SFRC beam (Fig. 14) tested by Swamy and Al-Ta'an (1981) is selected in present analysis. The mechanical properties of the concrete used for the beam is given in Table IV. Crimped steel fibers with the properties listed also in Table IV were used. Due to the symmetrical

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geometry and loading of the beam, half of the beam was considered in the analysis adopting three heterosis elements as illustrated in Fig. 15. The results of current analysis and experimental outcomes are given in terms of applied force - central displacement and strains of beam as given in Figs. 16-18.

According to the comparison between numerical and experimental outcomes in these figures, suitable agreement was observed specially by considering stiffness cases 2 and 4 in the present analysis. The difference in analytical outcomes with experimental values in Fig. 16 is attributed to the some approximate concepts in the present finite element analysis such as disregarding the effect of shear stirrups.

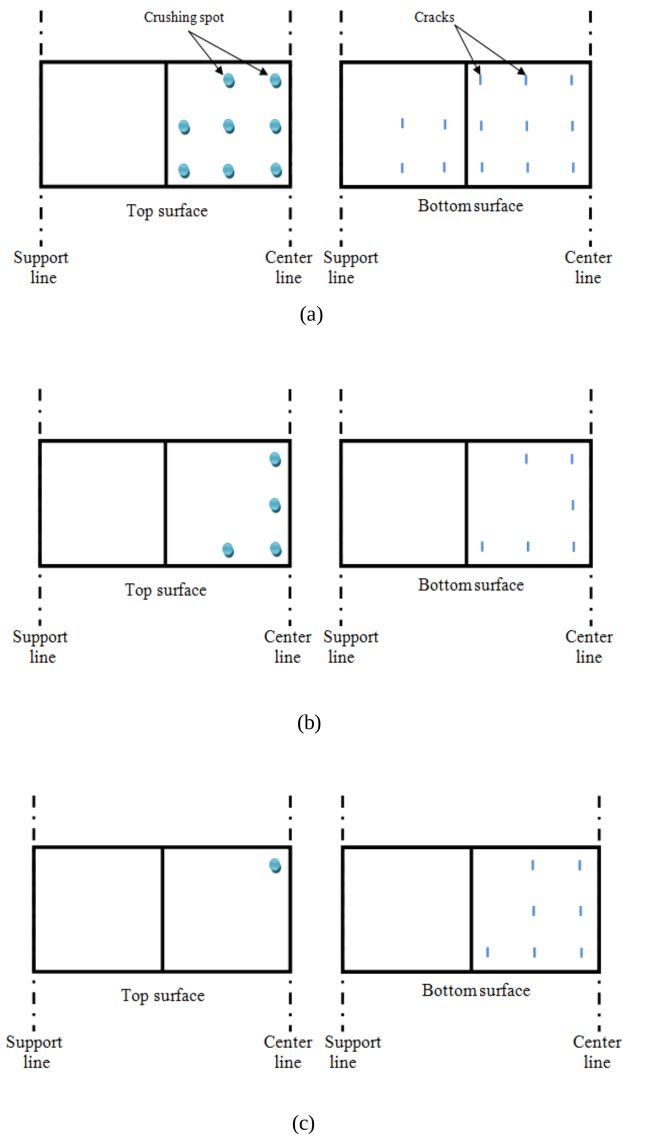

Fig. 12. Failure pattern for SFRC beam using present finite element procedure; (a) Failure at load of 120 kN for beam 1 with c=5mm, (b) Failure at load of 67 kN for beam 1 with c=15mm and (c) Failure at load of 64 kN for beam 1 with c=25mm.

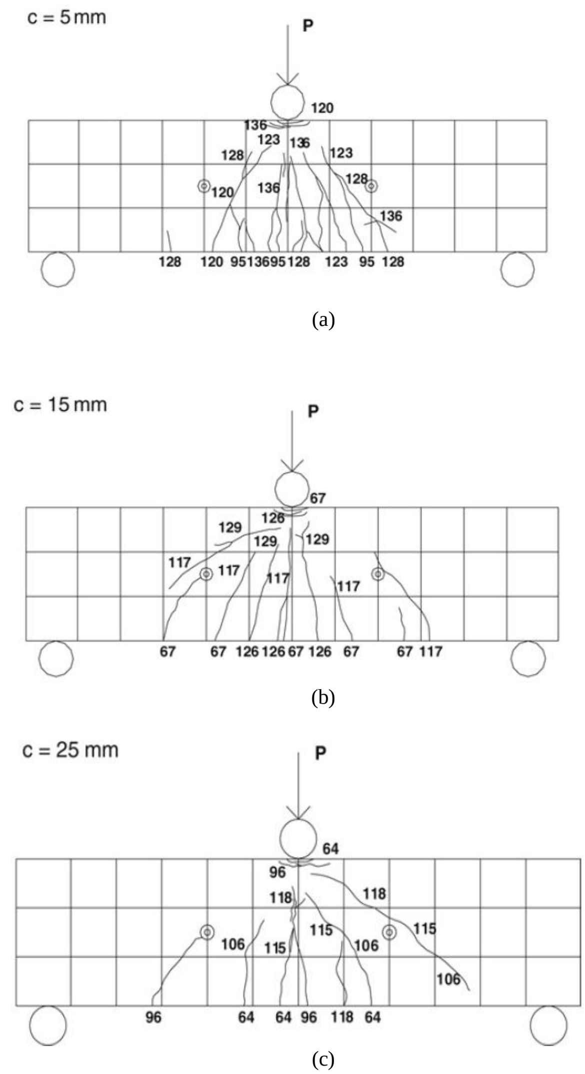

Fig. 13. Experimental failure pattern for SFRC beam 1 (Compione and Mangiavillano, 2008); (a) Failure for beam 1 for applied load 120, (b) Failure at load of 67 kN for beam 1 with c=15mm and (c) Failure for beam 1 for applied load 64 kN.

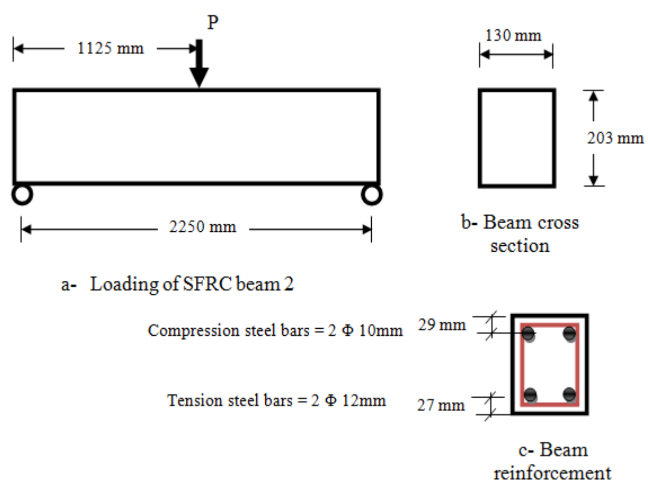

Fig. 14. SFRC beam 2.

TABLE IV
PROPERTIES OF CONCRETE USED FOR SFRC BEAM 2

Compressive strength MPa	28.40
Tensile strength MPa	5.80
Yield stress of steel bars MPa	475
Modulus of Elasticity of concrete MPa	29820
Fiber length mm	50
Fiber diameter mm	0.5
Fiber aspect ratio	100
Steel fiber content in concrete %	1

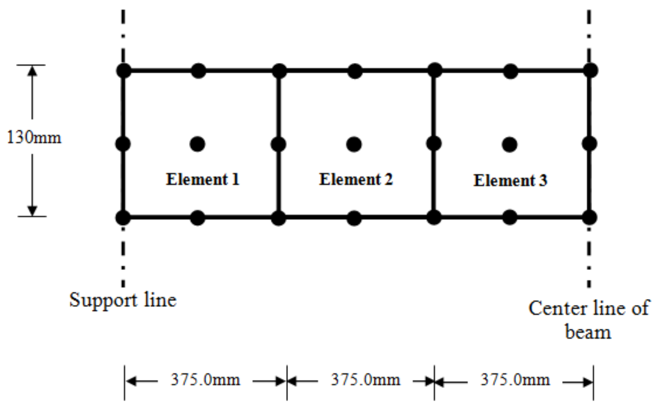

Fig. 15. Finite element mesh of SFRC beam 2.

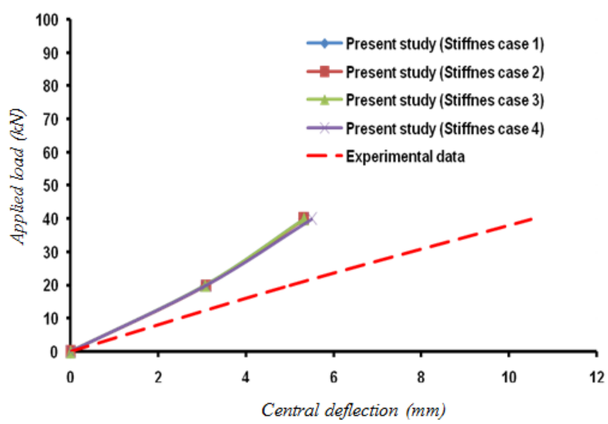

Fig. 16. Load-deflection curve for SFRC beam 2.

C. *SFRC beam with rectangular cross section and subjected to two point forces*

Shallow SFRC beam (Fig. 19) tested by Narayanan and Darwish (1987) was adopted in present finite element analysis. The properties of this concrete beam are given in Table V. Half of the beam was considered in analysis because of the condition of symmetry. Thus, four heterosis elements with ten concrete strata were used to model the half of beam as in Fig. 20. The static performance of the beam is represented in the form of displacement values at specific applied load magnitudes and ultimate applied load values.

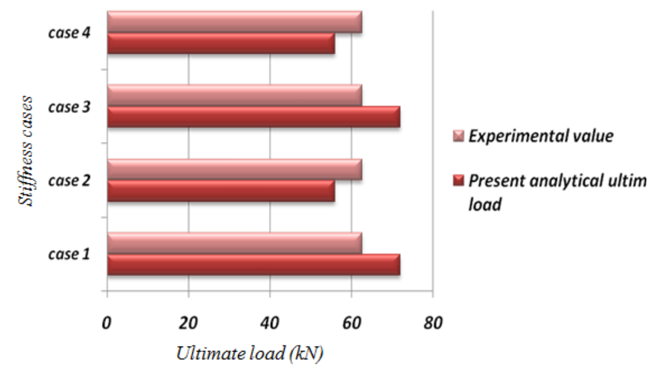

Fig. 17. Ultimate load for SFRC beam 2

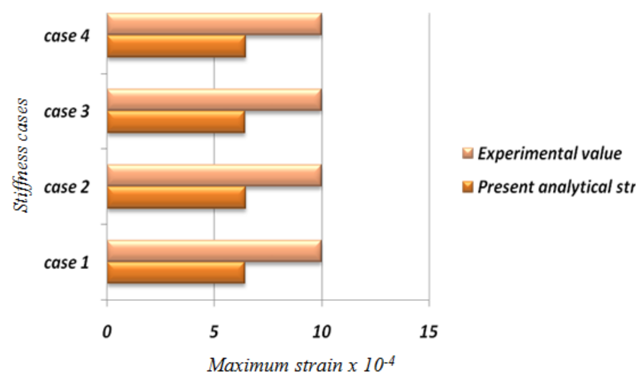

Fig. 18. Maximum longitudinal strains of tension steel bars for SFRC beam 2

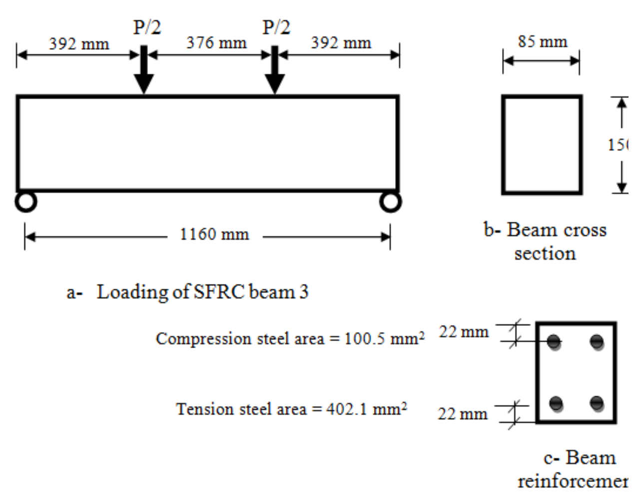

Fig. 19. SFRC beam 3.

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TABLE V
PROPERTIES OF REINFORCED CONCRETE USED FOR SFRC BEAM 3

Compressive strength MPa	71.90
Tensile strength MPa	6.03
Yield stress of steel bars MPa	530
Modulus of Elasticity of concrete MPa	29790
Fiber length mm	40
Fiber diameter mm	0.30
Fiber aspect ratio	133
Steel fiber content in concrete %	1

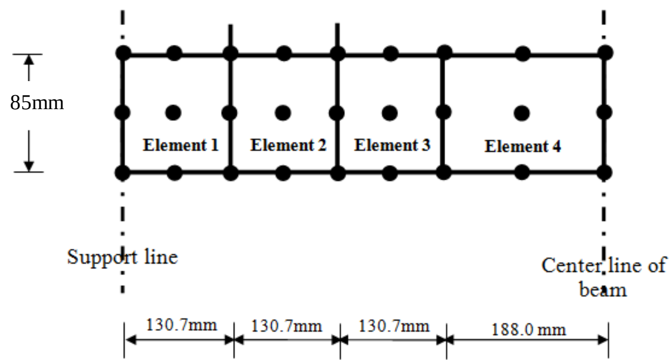

Fig. 20: Finite element mesh of SFRC beam 3.

Present numerical results are compared to the experimental outcomes as shown in Figs. 21-23, good harmony was observed. The adopting of case 4 of stiffness calculation is considered more suitable than other cases especially in determination of displacement values.

Generally, it is observed in the aforementioned results that the stiffness cases 2 and 4 give more reasonable outcomes. The using of tangent stiffness and stiffness in the second iteration is relatively more realistic due to the decreasing of error produced in numerical solution compared to the proposed initial stiffness condition.

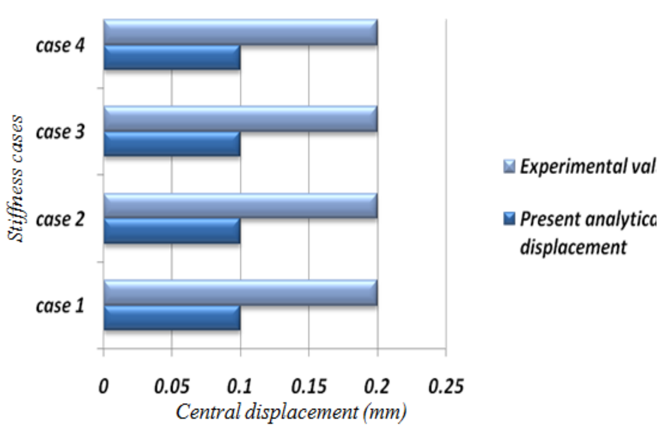

Fig. 21. Central deflection at load step of 12 kN of SFRC beam 3.

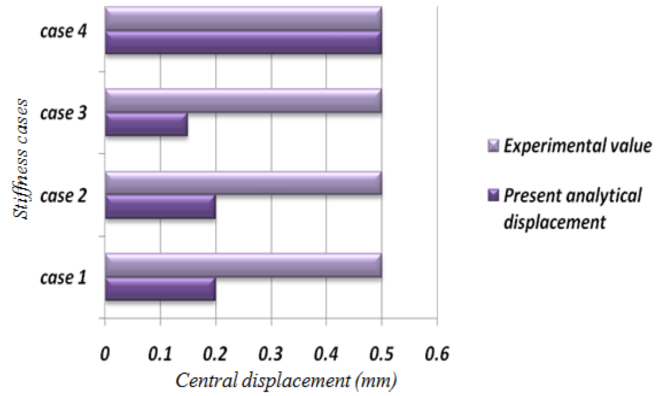

Fig. 22. Central deflection at load step of 20 kN of SFRC beam 3.

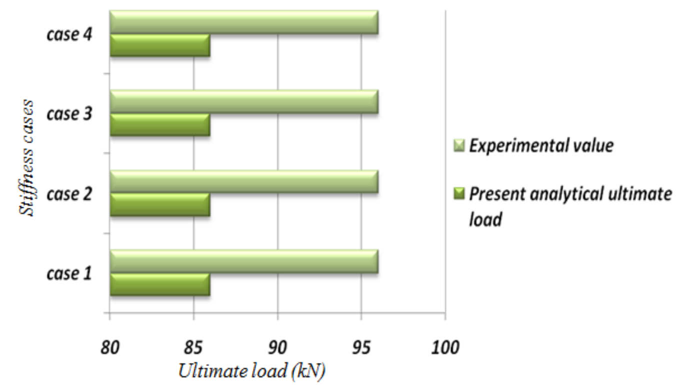

Fig. 23. Ultimate applied load for SFRC beam 3.

IV. CONCLUSIONS

In the present study, new and simple nonlinearities for simulation of SFRC performance were proposed depending on many experimental data. Finite element procedure has been developed for static analysis of SFRC beam based on using the proposed nonlinearities in formulation of the nine nodes heterosis elements. According to the outcomes of the aforementioned applications, it can be concluded that;

1) The proposed models for SFRC behavior are valid for static analysis purpose of SFRC beams that contain many steel fibers shapes and sizes.
2) The best results have been found in present finite element static analysis with considering the tangential stiffness matrix and stiffness matrix in second iteration of the load increment.

REFERENCES

Abdul-Razzak, A.A., and Ali, A.A.M., 2011. Modeling and numerical simulation of high strength fiber reinforced concrete corbels. *Applied Mathematical Modeling*, 35(6), pp.2901-2915.

Abdul-Razzak, A.A., and Ali, A.A.M., 2011. Influence of cracked concrete models on the nonlinear analysis of high strength steel fiber reinforced concrete corbels. *Composite Structures*, 93(9), pp.2277-2287.

Alavizadeh-Farhang, A., 1998. *Plain and steel fiber reinforced concrete beams subjected to combined mechanical and thermal loadings*. M.Sc. Thesis, Department of Structural Engineering, Royal Institute of Technology, Stockholm, Sweden.

Al-Ta'an, S.A. and Ezzadeen, N.A., 1995. Flexural analysis of reinforced fibrous concrete members using finite element method. *Computer and Structures*, 56(6), pp.1065-1072.

ANSYS, 2003. *Swanson Analysis System*. US.

Ashour, S.A., Wafa, F.F., and Kamal, M.I., 2000. Effect of the concrete compressive strength and tensile reinforcement ratio on the flexural behavior of fibrous concrete beams. *Engineering Structures*, 22(9), pp.1133–1146.

Bangash, M.Y.H., 1989. *Concrete and concrete applications*. London, England: Elsevier Science Publishers Ltd.

Bayramov, F., Tasdemir, C., and Tasdemir, M.A., 2004. Optimization of steel fiber reinforced concretes by means of statistical response surface method. *Cement and Concrete Composites*, 26(6), pp.665–675.

Bencardino, F., Rizzuti, L., Spadea, G., and Swamy, R.N., 2010. Experimental evaluation of fiber reinforced concrete fracture properties. *Composites Part B-Engineering*, 41(1), pp.17–24.

Compione, G., and Mangiavillano, M. L., 2008. Fibrous reinforced concrete beams in flexure: Experimental investigation, analytical modeling and design considerations. *Engineering Structures*, 30(11), pp.2970-2980.

Cucchiara, C., La Mendola, L., and Papia, M., 2004. Effectiveness of stirrups and steel fibers as shear reinforcement. *Cement and Concrete Composites*, 26(7), pp.777-786.

Dupont, D., and Vandewalle, L., 2002. *Bending capacity of steel fiber reinforced concrete SFRC beams*. In: International Congress on Challenges of Concrete Construction. Dundee, pp.81-90.

Ganesan, N., and Shivananda, K.P., 2002. *Spacing and width of cracks in polymer modified steel fiber reinforced concrete flexural members*. In: International Congress on Challenges of Concrete Construction, Dundee, pp.244-253.

Gopalaratnam, U.S., Shah, S.P., Batson, G.B., Criswell, M.E., Ramaksishran, U., and Wecharatara, M., 1991. Fracture toughness of fiber reinforced concrete. *ACI Materials Journal*, 8(4), pp.339-353.

Hartman, T., 1999. *Steel fiber reinforced concrete*. M.Sc. Thesis, Department of Structural Engineering, Royal Institute of Technology, Stockholm, Sweden.

Hasan, N.H.J., 2002. *Nonlinear finite element analysis of fibrous reinforced concrete slabs*. M.Sc. Thesis, University of Mosul.

Hemmaty, Y., 1998. *Modeling of the shear force transferred between cracks in reinforced concrete structures*. In: Proceedings of ANSYS Conference, Vol. 1, Pittsburgh, Pennsylvania.

Hsu, L.S., and Hsu, C.T.T., 1994. Stress–strain behavior of steel-fiber high-strength concrete under compression. *ACI Structural Journal*, 91(4), pp.448-457.

Huyse, L., Hemmaty, Y., and Vandewalle, L., 1994. *Finite element modeling of fiber reinforced concrete beams*. In: Proceedings of the ANSYS Conference, Vol. 2, Pittsburgh, Pennsylvania.

Koksal, F., Altun, F., Yigit, I., and Sahin, Y., 2008. Combined effect of silica fume and steel fiber on the mechanical properties of high strength concretes. *Construction and Building Materials*, 22(8), pp.1874–1880.

Kurihara, N., Kunieda, M., Kamada, T., Uchida, Y., and Rokugo, K., 2000. Tension softening diagrams and evaluation of properties of steel fiber reinforced concrete. *Engineering Fracture Mechanics*, 65(2-3), 235-245.

Lim, D.H., and Nawy, E.G., 2005. Behavior of plain and steel-fiber-reinforced high-strength concrete under uniaxial and biaxial compression. *Magazine of Concrete Research*, 57(10), pp.603-610.

Lin, W.T., Huang, R., Lee, C.L., and Hsu, H.M., 2008. Effect of steel fiber on the mechanical properties of cement-based composites containing silica fume. *Journal of Materials Science and Technology*, 6(3), pp.214–221.

Narayanan, R., and Darwish, I.Y.S., 1987. Use of steel fibers as shear reinforcement. *ACI Structural Journal*, 84(3), pp.216-227.

Ocean Heidelberg Cement Group, 1999. *Ocean concrete products, steel fiber reinforcement, working together to build our communities report*.

Paine, K.A., Elliott, K.S., and Paston, C.H., 2002. *Flexural toughness as a measure of shear strength and ductility of prestressed fiber reinforced concrete beams*. In: International Congress on Challenges of Concrete Construction, Dundee, pp.200-212.

Song, P.S., and Hwang, S., 2004. Mechanical properties of high-strength steel fiber reinforced concrete. *Construction and Building Materials*, 18(9), pp.669-673.

Swamy, R.N., and AL-Ta'an, S.A., 1981. Deformation and ultimate strength in flexure of reinforced concrete beams made with steel fiber concrete. *ACI Journal Proceedings*. 78(5), pp.395-405.

Thomas, J., and Ramaswamy, A., 2007. Mechanical properties of steel fiber-reinforced concrete. *ASCE Journal of Materials in Civil Engineering*, 19(5), pp.385-392.

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