International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Some Results on Regular Fuzzy Graphs

S Navaneetha Selvan[1], S Sherly[2]

[1]Assistant Professor, Department of Mathematics, VPMM Arts and Science College, Krishnankoil, Virudhunagar, Tamil Nadu 626 126.

[2]Assistant Professor, Department of Mathematics, Maria college of engineering and technology, Thiruvattaru, Tamil Nadu 629177.

Abstract

In this paper, Regular fuzzy graph, Totally Regular fuzzy graph, Partially Regular fuzzy graph, Full Regular fuzzy graph, Edge Regular fuzzy graph, K-totally edge regular fuzzy graph, Odd degree Fuzzy graph, Even degree Fuzzy graph, Cubic Fuzzy graphs are discussed.

Keywords: Regular fuzzy graph, Odd degree Fuzzy graph, Even degree Fuzzy graph, Cubic Fuzzy graph.

1. Introduction

In this paper, we consider only finite, simple, connected graphs. We denote the vertex set and the edge set of a graph G by $V(G)$ and $E(G)$ respectively. The degree of a vertex v is the number of edges incident at v, and it is denoted by $d(v)$. A graph G is regular if all its vertices have the same degree. The notion of fuzzy sets was introduced by Zadeh as a way of representing uncertainity and vagueness [24]. The first definition of fuzzy graph was introduced by Haufmann in 1973. In 1975, A. Rosenfeld introduced the concept of fuzzy graphs [5]. The theory of graph is an extremely useful tool for solving combinatorial problems in different areas. Irregular fuzzy graphs play a central role in combinatorics and theoretical computer science. Nagoorgani and Radha introduced the concept of degree, total degree, regular fuzzy graphs in 2008 [3]. Nagoorgani and Latha introduced the concept of irregular fuzzy graphs, neighbourly irregular fuzzy graphs and highly irregular fuzzy graphs in 2012 [4]. N.R.Santhi Maheswari and C.Sekar introduced $(2,k)$ −regular fuzzy graphs and totally $(2,k)$ −regular fuzzy graphs, $(r,2,k)$ −regular fuzzy graphs, (m,k) − regular fuzzy graphs and (r,m,k) − regular fuzzy graphs [6,10,11,12]. N.R.Santhi Maheswari and C. Sekar introduced 2-neighbourly irregular fuzzy graphs and m −neighbourly irregular fuzzy graphs [17,9]. N.R.Santhi Maheswari and C.Sekar introduced an edge irregular fuzzy graphs, neighbourly edge irregular fuzzy graphs and strongly edge irregular fuzzy graph [13,7,14]. D. S. Cao, introduced 2-degree of vertex v is the the sum of the degrees of the vertices adjacent to v and it is denoted by $t(v)$ [2]. A.Yu, M.Lu and F.Tian, introduced pseudo degree (average degree) of a vertex v is $(t(v))/d(v)$, where $d(v)$, is the number of edges incident at the vertex v [1]. N.R.Santhi Maheswari and C.Sekar introduced 2- degree of a vertex in fuzzy graphs , pseudo degree of a vertex in fuzzy graph and pseudo regular fuzzy graphs [8]. N.R Santhi Maheswari and M.Sutha introduced concept of pseudo irregular fuzzy graphs and highly pseudo irregular fuzzy graphs[15]. N.R.Santhi Maheswari and M.Rajeswari introduced the concept of strongly pseudo irregular fuzzy graphs [16]. Selvam Avadayappan and G.Mahadevan call this 2-degree of a vertex as support of a vertex. Selvam Avadayappan, M,Bhuvaneshwari and R.Sinthu introduced support neighbourly irregular graphs [23]. N.R.Santhi Maheswari and K.Amutha introduced support neighbourly edge irregular graphs and 1 neighbourly edge irregular graphs, Pseudo Edge Regular and Pseudo Neighbourly edge irregular graphs [19,20,21]. N.R.Santhi Maheswari and K.Priyatharcini introduced support highly irregular graphs [22] . N.R.Santhi Maheswari and V,Jeyapratha introduced the concept of neighbourly pseudo irregular fuzzy graphs[18]. These motivate us to discuss Regular fuzzy graph, Totally Regular fuzzy graph, Partially Regular fuzzy graph, Full Regular fuzzy graph, Edge Regular fuzzy graph, K-totally edge regular fuzzy graph, Odd degree Fuzzy graph, Even degree Fuzzy graph, Cubic Fuzzy graphs and some of its properties.

2. Preliminaries

Definition 2.1. In a graph G all the vertices have same degree k then the graph G is called Regular graph or k −Regular graph.

Definition 2.2. In a graph G all the edges have the same degree k then the graph G is called edge regular graph or k −edge regular graph.

Definition 2.3. Let v be a non-empty finite set and $E \subseteq v \times v$. A fuzzy graph $G: (\sigma, \mu)$ is a pair of functions $\sigma: v \to [0,1]$ and $\mu: E \to [0,1]$ such that $\mu(x, y) \leq \alpha(x) \wedge \sigma(y)$ for all $x, y \in V$ where σ is a fuzzy subset of an non-empty set V and μ is a symmetric fuzzy relation on σ. The underlying crisp graph of $G: (\sigma, \mu)$ is denoted by $G *: (V, E)$.

Definition 2.4. Let $FG(\sigma, \mu)$ be a fuzzy graph on $G(V, E)$. The degree of a vertex σ_i is defined by $d_{fg}(\sigma_i) = \Sigma\mu(\sigma_i\sigma_j)$ for $\sigma_i \neq \sigma_j$.

Definition 2.5. The Maximum degree of the Vertex of $FG(\sigma, \mu)$ is $\Delta(FG) = \vee\, d_{FG}(\sigma_i) forall \sigma_i \in \sigma$.The Minimum degree of the vertex of $FG(\sigma, \mu)$ is $\Delta(FG) = \wedge\, d_{FG}(\sigma i) forall \sigma_i \in \sigma$.

Definition 2.6. Let $FG(\sigma, \mu)$ be a fuzzy graph on $G(V, E)$, The total degree of a vertex is defined by $td_{FG}(\sigma_i) = d_{FG}(\sigma_i) + \sigma(\sigma_i)$.

Definition 2.7. Let $FG(\sigma, \mu)$ be a fuzzy graph on $G(V, E)$ if each vertex in G has a same degree K then $FG(\sigma, \mu)$ is said to be Regular fuzzy graph or K-Regular fuzzy graph.

Definition 2.8. Let $FG(\sigma, \mu)$ be a fuzzy graph on $G(V, E)$ if each vertex in G has a same total degree Kthen $FG(\sigma, \mu)$ is said to be Totally Regular fuzzy graph or K- Totally Regular fuzzy graph.

Definition 2.9. If the graph G is regular then $FG(\sigma, \mu)$ is said to be Partially Regular fuzzy graph.

Definition 2.10. If the fuzzy graph $FG(\sigma, \mu)$ is satisfying both regular fuzzy graph and partially regular fuzzy graph, then $FG(\sigma, \mu)$ is said to be a Full Regular fuzzy graph.

Definition 2.11. Let $FG(\sigma, \mu)$be a fuzzy graph on $G(V, E)$ if each edge in $FG(\sigma, \mu)$ has same degree Kthen $FG(\sigma, \mu)$ is said to be an Edge Regular fuzzy graph.

Definition 2.12. Let $FG(\sigma, \mu)$ be a fuzzy graph on $G(V, E)$ if each edge in $FG(\sigma, \mu)$ has same total degree K then $FG(\sigma, \mu)$ is said to be Totally Edge Regular fuzzy graph or K-totally edge regular fuzzy graph.

3. Some Properties of Regular fuzzy graphs

Theorem 3.1. Let $G: (\sigma, \mu)$ be a fuzzy graph on $G *: (V, E)$ Then $\Sigma d_G(v) = 2S(G)$.

Proof : Let $G: (\sigma, \mu)$ can be a Fuzzy graph on $G(V, E)$. Then the degree of a vertex σ_i is defined by,

$d_{FG}(\sigma_i) = \Sigma\mu(\sigma_i\sigma_j) for \sigma_i \neq \sigma_j$.

$\Sigma_{i=1}^{n} d_{FG}(\sigma_i) = d_{FG}(\sigma_1) + d_{FG}(\sigma_2) + d_{FG}(\sigma_3) + \ldots\ldots + d_{FG}(\sigma_{n-1}) + d_{FG}(\sigma_n)$.

$d_{FG}(\sigma_1) = \mu(\sigma_1\sigma_2) + \mu(\sigma_1\sigma_3) + \mu(\sigma_1\sigma_4) + \ldots\ldots + \mu(\sigma_1\sigma_{n-1}) + \mu(\sigma_1\sigma_n)$.

$d_{FG}(\sigma_2) = \mu(\sigma_2\sigma_1) + \mu(\sigma_2\sigma_3) + \mu(\sigma_2\sigma_4) + \ldots\ldots + \mu(\sigma_2\sigma_n - 1) + \mu(\sigma_2\sigma_n)$.

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$d_{FG}(\sigma_n) = \mu(\sigma_n\sigma_1) + \mu(\sigma_n\sigma_3) + \mu(\sigma_n\sigma_4) + \ldots\ldots + \mu(\sigma_n\sigma_{n-1})$.

$\Sigma_{i=1}^{n} d_{FG}(\sigma_1) = \mu(\sigma_1\sigma_2) + \mu(\sigma_1\sigma_3) + \mu(\sigma_1\sigma_4) + \ldots\ldots + \mu(\sigma_1\sigma_{n-1}) + \mu(\sigma_1\sigma_n) + \mu(\sigma_2\sigma_1) + \mu(\sigma_2\sigma_3) + \mu(\sigma_2\sigma_4) + \ldots\ldots + \mu(\sigma_2\sigma_{n-1}) + \mu(\sigma_2\sigma_n) + \ldots\ldots + \mu(\sigma_n\sigma_1) + \mu(\sigma_n\sigma_2) + \mu(\sigma_n\sigma_4) + \ldots\ldots + \mu(\sigma_n\sigma_{n-1})$.

$= 2\mu(\sigma_1\sigma_2) + 2\mu(\sigma_1\sigma_3) + \ldots\ldots + 2\mu(\sigma_1\sigma_{n-1}) + 2\mu(\sigma_1\sigma_n) + 2\mu(\sigma_2\sigma_3) + 2\mu(\sigma_2\sigma_4) + \ldots\ldots + 2\mu(\sigma_2\sigma_{n-1}) + 2\mu(\sigma_2\sigma_n) + \ldots\ldots + 2\mu(\sigma_1\sigma_n) + 2\mu(\sigma_2\sigma_2) + \ldots\ldots + 2\mu(\sigma_{n-1}\sigma_n)$.

$= 2[\mu(\sigma_1\sigma_2) + \mu(\sigma_1\sigma_3) + \ldots\ldots + \mu(\sigma_1\sigma_{n-1}) + \mu(\sigma_1\sigma_n) + \mu(\sigma_2\sigma_3) + \mu(\sigma_2\sigma_4) + \ldots\ldots + \mu(\sigma_2\sigma_{n-1}) + \mu(\sigma_2\sigma_n) + \ldots\ldots + \mu(\sigma_1\sigma_n) + \mu(\sigma_2\sigma_2) + \ldots\ldots + 2\mu(\sigma_{n-1}\sigma_n)$.

$= 2[\Sigma\mu(\sigma_i\sigma_j)]$.

$= 2S(G)$.

Theorem 3.2. Let $G: (\sigma, \mu)$ be a fuzzy graph on $G*: (V, E)$ then $\Sigma td_{FG}(\sigma_i) = 2S(G) + O(G)$

Proof : Let $G: (\sigma, \mu)$ be a fuzzy graph on $G*: (V, E)$ and the vertices are $\sigma = \{\sigma_1, \sigma_2, \ldots \sigma_n\}$

$td_{FG}(\sigma_i) = d_{FG}(\sigma_i) + \sigma(\sigma_j)$, (by Definition 2.6)

$\Sigma td_{FG}(\sigma_i) = \Sigma_{i=1}^{n} d_{FG}(\sigma_i) + \Sigma\sigma(\sigma_j)$,

$\Sigma_{i=1}^{n} d_{FG}(\sigma_i) = 2S(G)$ (by theorem 3.1) , here $\Sigma\sigma(\sigma_i) = O(G)$

Hence $\Sigma td_{FG}(\sigma_i) = 2S(G) + O(G)$.

Theorem 3.3. let $FG(\sigma, \mu)$ be a fuzzy graph on a cycle $G(V, E)$, then $\Sigma d_{FG}(\sigma_i) = \Sigma d_{FG}(\sigma_i\sigma_j)$

Proof : Let $FG(\sigma, \mu)$ be a fuzzy graph on a cycle $G(V, E)$

We have to prove that $\Sigma d_{FG}(\sigma_i) = \Sigma d_{FG}(\sigma_i\sigma_j)$

This shows that,

$\Sigma d_{FG}(\sigma_i\sigma_j) = 2S(FG) \to (1)$

Since $FG(\sigma, \mu)$be a fuzzy graph on a cycle $G(V, E)$ Cleary it is a cycle. $c = \sigma_1\sigma_2\sigma_3\ldots\ldots\sigma_n\sigma_1$.

$\Sigma d_{FG}(\sigma_i\sigma_j) = d_{FG}(\sigma_1\sigma_2) + d_{FG}(\sigma_2\sigma_3) + d_{FG}(\sigma_3\sigma_4) + \ldots\ldots + d_{FG}(\sigma_n\sigma_1)$

$d_{FG}(\sigma_1\sigma_2) = d_{FG}(\sigma_1) + d_{FG}(\sigma_2) - 2\mu(\sigma_1\sigma_2)$

$d_{FG}(\sigma_2\sigma_3) = d_{FG}(\sigma_2) + d_{FG}(\sigma_3) - 2\mu(\sigma_2\sigma_3)$

$d_{FG}(\sigma_3\sigma_4) = d_{FG}(\sigma_3) + d_{FG}(\sigma_4) - 2\mu(\sigma_3\sigma_4)$

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$d_{FG}(\sigma_n\sigma_1) = d_{FG}(\sigma_n) + d_{FG}(\sigma_1) - 2\mu(\sigma_n\sigma_1)$

$\Sigma d_{FG}(\sigma_i\sigma_j) = 2d_{FG}(\sigma_1) + 2d_{FG}(\sigma_2) + 2d_{FG}(\sigma_3) + \ldots\ldots + 2d_{FG}(\sigma_n) - 2\mu(\sigma_n\sigma_1)\Sigma d_{FG}(\sigma_i\sigma_j)$

$= 2[d_{FG}(\sigma_1) + d_{FG}(\sigma_2) + d_{FG}(\sigma_3) + \ldots\ldots + d_{FG}(\sigma n)] - 2[\mu(\sigma_1\sigma_2) + \mu(\sigma_2\sigma_3) + \mu(\sigma_3\sigma_4) + \mu(\sigma_n\sigma_1)$

$\Sigma d_{FG}(\sigma_i\sigma_j) = 2[2(S(G)] - 2S(G)$.

$\Sigma d_{FG}(\sigma_i\sigma_j) = 4S(G) - 2S(G)$

$\Sigma d_{FG}(\sigma_i\sigma_j) = 2S(G) \to (2)$ by (1) and (2) we get, $\Sigma d_{FG}(\sigma_i) = \Sigma d_{FG}(\sigma_i\sigma_j)$.

Theorem 3.4. Let $FG(\sigma, \mu)$ be a fuzzy graph on $G(V, E)$. Then μ is a constant function if and only if the following are equivalent:

(1) $FG(\sigma, \mu)$ is an edge regular Fuzzy graph.

(2) $FG(\sigma, \mu)$ is an totally edge regular Fuzzy graph.

Proof : Let $FG(\sigma,\mu)$ be a fuzzy graph on $G(V,E)$.Suppose that μ = c is a constant function. Then $\mu(\sigma_i\sigma_j) = c$ for every, $\sigma_i\sigma_j \in \mu$ where c is a constant.

(1) ⇒ (2) Assume that $FG(\sigma,\mu)$ is a k_1- edge regular Fuzzy graph. To show $FG(\sigma,\mu)$ is a totally edge regular fuzzy graph. $d_{FG}(\sigma_i\sigma_j) = k_1$ for all $\sigma_i\sigma_j \in \mu$, $td_{FG}(\sigma_i\sigma_j) = d_{FG}(\sigma_i\sigma_j) + \mu(\sigma_i\sigma_j)$ for all $\sigma_i\sigma_j \in \mu$ $td_{FG}(\sigma_i\sigma_j) = k_1 + c$ for all $\sigma_i\sigma_j \in \mu$ Hence G is a $(k_1 + c)$ −totally edge regular fuzzy graph.

(2) ⇒ (1) Now suppose that $FG(\sigma,\mu)$ is a k_2 −totally edge regular fuzzy graph. Then $td_{FG}(\sigma_i\sigma_j) = k_2$ for all $\sigma_i\sigma_j \in \mu$ To show that $FG(\sigma,\mu)$ is the edge regular fuzzy graph. $d_{FG}(\sigma_i\sigma_j) + \mu(\sigma_i\sigma_j) = k_2$ for all $\sigma_i\sigma_j \in \mu$, $d_{FG}(\sigma_i\sigma_j) = k_2 - \mu(\sigma_i\sigma_j)$ for all $\sigma_i\sigma_j \in \mu$, $d_{FG}(\sigma_i\sigma_j) = k_2 - c$ for all $\sigma_i\sigma_j \in \mu$ Hence $FG(\sigma,\mu)$ is a $k_2 -$ edge regular fuzzy graph. Hence (1) and (2) are equivalent.

Conversely, Assume that (1) and (2) are equivalent. $FG(\sigma,\mu)$ is an edge regular Fuzzy graph if and only if $FG(\sigma,\mu)$ is an totally edge regular Fuzzy graph. To prove that μ is a constant function. Suppose μ is not a constant function. Then $\mu(\sigma_i\sigma_j) \neq \mu(\sigma_k\sigma_l)$ for at least one pair of edges $\sigma_k\sigma_l, \sigma_i\sigma_j \in \mu$. Let $FG(\sigma,\mu)$ be a k - edge regular Fuzzy graph. $d_{FG}(\sigma_i\sigma_j) = d_{FG}(\sigma_k\sigma_l) = k$ for all $\sigma_i\sigma_j, \sigma_k\sigma_l \in \mu. td_{FG}(\sigma_i\sigma_j) = d_{FG}(\sigma_i\sigma_j) + \mu(\sigma_i\sigma_j)$ for all $\sigma_i\sigma_j \in \mu$. $td_{FG}(\sigma_i\sigma_j) = k + \mu(\sigma_i\sigma_j)$ for all $\sigma_i\sigma_j \in \mu. td_{FG}(\sigma_k\sigma_l) = d_{FG}(\sigma_k\sigma_l) + \mu(\sigma_k\sigma_l)$ for all $\sigma_k\sigma_l \in \mu$. Since $\mu(\sigma_i\sigma_j) \neq \mu(\sigma_k\sigma_l)$ so $td_{FG}(\sigma_i\sigma_j) \neq td_{FG}(\sigma_k\sigma_l)$Hence $FG(\sigma,\mu)$ is not a totally edge regular fuzzy graph. Which is a contradiction to our assumption. Now let $FG(\sigma,\mu)$ is a totally edge regular fuzzy graph. $td_{FG}(\sigma_i\sigma_j) = td_{FG}(\sigma_k\sigma_l)$ $d_{FG}(\sigma_i\sigma_j) + \mu(\sigma_i\sigma_j) = d_{FG}(\sigma_k\sigma_l) - \mu(\sigma_k\sigma_l)$, $d_{FG}(\sigma_i\sigma_j) - d_{FG}(\sigma_k\sigma_l) = \mu(\sigma_i\sigma_j) - \mu(\sigma_k\sigma_l)$. $d_{FG}(\sigma_i\sigma_j) - d_{FG}(\sigma_k\sigma_l) \neq 0$ [since $\mu(\sigma_i\sigma_j) \neq \mu(\sigma_k\sigma_l)$] Then $d_{FG}(\sigma_i\sigma_j) \neq d_{FG}(\sigma_k\sigma_l)$. $FG(\sigma,\mu)$is not a edge regular fuzzy graph.

Theorem 3.5. If a fuzzy graph $FG(\sigma,\mu)$ is both edge regular and totally edge regular, then μ is a constant function.

Proof : Let $FG(\sigma,\mu)$ be a fuzzy graph, k_1 −edge regular fuzzy graph and k_2 totally edge regular fuzzy graph. Then $d_{FG}(\sigma_i\sigma_j) = k_1$ for all $\sigma_i\sigma_j \in \mu$. and $td_{FG}(\sigma_i\sigma_j) = k_2$ for all $\sigma_i\sigma_j \in \mu. td_{FG}(\sigma_i\sigma_j) + \mu(\sigma_i\sigma_j) = k_2$ for all $\sigma_i\sigma_j \in \mu. \mu(\sigma_i\sigma_j) = k_2 - k_1$ for all $\sigma_i\sigma_j \in \mu$.Hence μ is a constant function.

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