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# NOVEL SIGN OF SUPER EDGE-MAGIC GRAPH

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**Abstract:** In this paper, we introduce a new concept of super edge-magic sequence (SEMS) of a super edge-magic graph (SEMG) with p vertices and q edges. The super edge-magic sequence of natural numbers is denoted by $< x_i >$, $1 \leq i \leq q$. This sequence need not to be monotonic. In this track, we also drive some families of super edge-magic graphs from fabrication of new super edge-magic sequences by considering additional parameter. We complete this paper by discussing the special case like monotonic sequences related to the super edge-magic sequence.

**AMS Subject Classification:** 05C78,05C99
**Key Words:** edge-magic graph, super edge-magic graph, super edge-magic sequence

## 1. Introduction

### 1.1. Background of Edge-Magic and Super Edge-Magic Graphs

Kotzig and Rosa introduced the concepts of magic valuation [11]. Ringel and Llado [15] called this type of valuation as edge-magic labeling. Enomoto et. al.[4] restricted the notion of edge -magic labeling of a graph to obtain the definition of super edge-magic labeling. A (p,q) graph G is called *edge-magic* if there exists a bijective function $f : V(G) \cup E(G) \longrightarrow \{1, 2, 3, \ldots, p + q\}$ such

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that $f(u) + f(v) + f(uv) = k$ is a magic constant for any edge uv $\in$E(G). Moreover, G is said to be *super edge-magic*if $f(V(G)) \longrightarrow \{1, 2, 3, \ldots, p\}$ . The following Lemma from [13] provides a necessary and sufficient condition for a graph to be super edge-magic.

**Lemma 1.1.** *A graph G with p vertices and q edges is super edge-magic if and only if there exists a bijective function $f : V(G) \longrightarrow \{1, 2, 3, \ldots, p\}$ such that the set $S = \{f(x) + f(y)/xy \in E(G)\}$ consists of q consecutive integers. In such a case, f extends to a super edge-magic total labeling of G with the magic constant $c = p + q + min(S)$.*

**Lemma 1.2.** *If a graph G with p vertices and q edges is super edge-magic then q≤2p-3.*

**Lemma 1.3.** *Let G be a triangle free super edge-magic graph with p (≥4) vertices and q edges. Then, q≤ $2p - 5$.*

### 1.2. Road Map of the Paper

The rest of the paper is organized as follows: In Section 2, we introduce the concept of super edge-magic sequence and construction of SEMG from SEMS. Also we give the limitations and upshots of super edge-magic sequence. Section 3, includes fabrication of new super edge-magic sequences and we drive some families of super edge-magic graphs. The last section covers a special case of sequence like monotonic sequence with their behavior in SEMS.

## 2. Proposed Work

### 2.1. Definition and Construction

Now we define the concept of super edge-magic sequence and transmit it to the graph. We describe super edge-magic sequence analogously for graceful sequence [1], [2] and [3].

**Definition 2.1.** (Super Edge-Magic Sequence) Let G be a super edge magic graph with p vertices and q edges. Here we introduce a new term i.e. a constant of super edge-magic sequence and is denoted by $\alpha^*$. A Sequence $< x_i >$ is said to be *super edge- magic sequence* if

$$\max_{1\le i\le q}\{2x_i + i\} < \alpha^* + q \le p + \min_{1\le i\le q}\{x_i + i\}......(2.1.a)$$

Where $x_i$ is always the lower end vertex of the edge label p + i, $1 \leq i \leq q$ i.e., $x_i$ = $\min\{f(x), f(y)/xy \in E(G)\}$ and $\alpha^* = \min(S)$, Where $S = \{f(x)+f(y)/xy \in E(G)\}$. We illustrate a super edge-magic sequence of Figure 1. SEMS of a

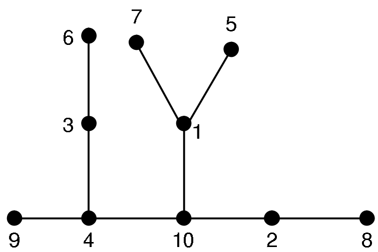



Figure 1

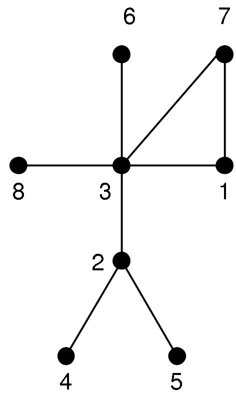



Figure 2

SEM Graph : Suppose ( 4,4,2,1,2,3,1,3,1) is a given sequence. For $1 \leq i \leq q$, $max\{2x_i + i\} = 14, min\{x_i + i\} = 5, \alpha^* = 6, p = 10, q = 9$. Then above data satisfies the condition (2.1.a).

**Note 2.1.** In this entire paper sequence means super edge-magic sequence.

### 2.2. Edifice of a Super Edge-Magic Graph from the Sequence

Let $(x_1, x_2, x_3, \ldots, x_q)$ be the sequence having 'q' terms. Compute $\alpha^*$ and p using the condition (2.1.a) as follows:

$$Letm = \max_{1 \leq i \leq q}\{2x_i + i\} andn = \min_{1 \leq i \leq q}\{x_i + i\}$$

Then by (2.1.a), $m < \alpha^* + q \leq p + n$. In this construction, $\alpha^*$ is independent for $\alpha^* \geq m - q + 1$. Based on particular$\alpha^*$, and by (2.1.a) choose $p \geq \alpha^* + q - n$. For every $\alpha^*$, there exist many p values such that all they must give super edge-magic graphs. Here we note that each p in this domain, the super edge-magic graph is unique. Identify the edges of super edge-magic graph corresponding a particular $\alpha^*$ and $'p'$ by the following way:

1.

The super edge-magic graph can be drawn by identifying all the edges like above.

**Concrete Example.** Suppose the given sequence is( 3,3,3,1,2,2,2,1), q=8, m = 11 and n = 4. On simplification of (2.1.a), we obtain3 $< \alpha^* \leq p -$ 4. The possibilities of $\alpha^*$ and p is respectively: $\alpha^* = \{4, 5, 6, \ldots, \}$ and p $=\{8, 9, 10, \ldots, \}$. In this domain of $\alpha^*$ and p, given sequence is super edge-magic sequence. For $\alpha^*$ =4, p= {8,9,10,...}.If$\alpha^* = 4$, and we select appropriate p = 8. We identify the edges by the following way:

Then the super edge-magic graph is shown in Figure 2

### 2.3. Limitations and Upshots of Super Edge-Magic Sequence

**Lemma 2.3.1.** *Let$(x_1, x_2, \ldots, x_q)$ be any super edge-magic sequence. $x_i$ denotes lower end vertex of the edge label $p + i$, $1 \leq i \leq q$ Then lower end vertex is always strictly less than the upper end vertex,i.e., $x_i < \alpha^* + q - i - x_i$ and upper end vertex is less than or equal to p.*

*Proof.* Let $(x_1, x_2, \ldots, x_q)$ be any super edge-magic sequence. Then by definition (2.1), this sequence satisfies the condition (2.1.a).

From LHS of (2.1.a): $x_i < \alpha * +q - i - x_i$ for all i, $1 \leq i \leq q$ ........ (2.3.a)

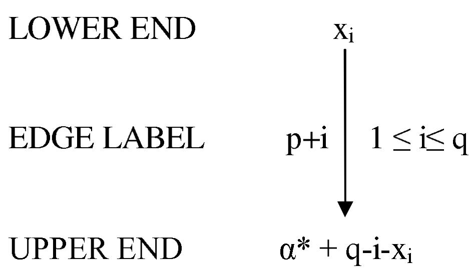
From RHS of (2.1.a): $\alpha * +q - i - x_i \leq p$ for all i, $1 \leq i \leq q$ ........ (2.3.b)

Also from (2.3.a) and (2.3.b), $x_i < \alpha * +q - i - x_i \leq p$ This completes the proof.

**Proposition 2.3.1.** *Let $< x_i >$, $1 \leq i \leq q$ be any super edge-magic sequence. The lower end vertex is at most p-1. i.e., $x_i \leq p - 1$.*

**Theorem 2.3.1.** *A graph is a super edge-magic graph if and only if G has super edge- magic sequence.*

*Proof.* Necessary Part. Let $(x_1, x_2, \ldots, x_q)$ be super edge-magic sequence. Then by definition (2.1), it has one super edge-magic graph.



Sufficient Part. Let us assume that G is super edge-magic. Here $\alpha* = min\{f(u) + f(v)/uv \in E(G)\}$ and $S = \{\alpha*, \alpha * +1, \alpha * +2, \ldots, \alpha * +q - 1\}$ has "$q$" consecutive integers. i.e.,$S = \{\alpha * +q - i/1 \leq i \leq q\}$ For each edge e=uv $\in E(G)$, $x_i = min\{f(u), f(v)/f(u) + f(v) = \alpha * +q - i/1 \leq i \leq q\}$ The other end is$\alpha * +q - i - x_i, \forall i, 1 \leq i \leq q$. By the second part of the lemma (2.3.1),

$$\alpha * +q \leq p + \min_{1 \leq i \leq q} \{x_i + i\} ....(2.3.c)$$

And the first part of the lemma (2.3.1),

$$\max_{1 \leq i \leq q} \{2x_i + i\} < \alpha * +q ....(2.3.d)$$

From (2.3.c) and (2.3.d), $(x_1, x_2, \ldots, x_q)$ is super edge-magic sequence. This completes the proof.

## 3. Fabrication of New Super Edge-magic Sequences

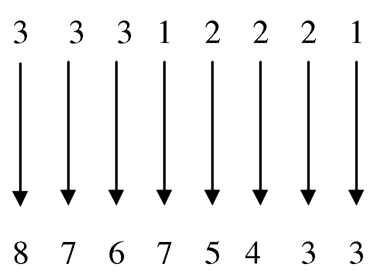
In this section, we fabricate new SEMS of SEMG by means of extension. We will do this construction as explained analogously in [1], [2].

**Theorem 3.1.** *If$(x_1, x_2, \ldots, x_q)$ represents a super edge-magic sequence of a graph G on "$q$" edges with*

$$\alpha * (< xi >) = \max_{1 \leq i \leq q} \{2x_i + i\} + 1 - q ......(3.a)$$

$$p(< x_i >) = \max_{1 \leq i \leq q} \{2x_i + i\} - \min_{1 \leq i \leq q} \{x_i + i\} + 1 ......(3.b)$$

*Then the sequence $(x^* + 1 - x_1, x^* + 1 - x_2, \ldots, x^* + 1 - x_{q-1}, x^* + 1 - x_q, x_1, x_2, \ldots, x_q)$ represents super edge-magic sequence on 2q edges with same $\alpha*$, for $x^*= \max\{x_i/1 \leq i \leq q\}$.*



*Proof.* Let $y_i = x^* + 1 - x_i,\ \ 1 \leq i \leq q\ y_q + i = x_i\ ,\ \ \ 1 \leq i \leq q$ Then the sequence becomes: $(y_1, y_2, y_3 \dots y_q, y_{q+1}, \dots, y_{2q})$

$$\max_{1 \leq i \leq q} \{2y_i + i\} \leq 2x^* + q......(3.c)$$

Suppose $x^*$ is occurring in the position of the least label $'r'$ in the sequence $< x_i >$

$$2x^* + q < 2x^* + q + r \leq \max_{1 \leq i \leq q} \{2y_{q+i} + q + i\}$$

$$= \max_{1 \leq i \leq q} \{2x_i + i\} + q$$

$$= \alpha * (< x_i >) + 2q - 1 by (3.a)$$

$2x * +q < \alpha * (< x_i >) + 2q - 1......(3.d)$

$$\max_{q+1 \leq i \leq 2q} \{2y_i + i\} = \max_{1 \leq i \leq q} \{2x_i + i\} + q$$

$$\max_{q+1 \leq i \leq 2q} \{2y_i + i\} = \alpha * (< x_i >) + 2q - 1......(3.e)$$

using (3.c) and (3.e)

$$\max_{1 \leq i \leq 2q} \{2y_i + i\} = \alpha * (< x_i >) + 2q - 1......(3.f)$$

$$Byapplying (3.a), \alpha * (< y_i >) = \max_{1 \leq i \leq 2q} \{2y_i + i\} + 1 - 2q$$

$$= \alpha * (< x_i >) (by 3.f)$$

$\alpha * (< y_i >) = \alpha * (< x_i >)$.

This completes the proof.

**Corollary 3.1.** *If* $(x^* + 1 - x_1, x^* + 1 - x_2, \dots, x^* + 1 - x_{q-1}, x^* + 1 - x_q, x_1, x_2, \dots, x_q)$ *represents super edge-magic sequence on 2q edges satisfying the conditions in theorem 3.1 then the number of vertices is given by*

$$\alpha * (< x_i >) + 2q - \min_{1 \leq i \leq 2q} \{y_i + i\}$$

.

*Proof.* Using the Theorem 3.1:

$$\min_{1 \leq i \leq 2q} \{y_i + i\} = \min_{1 \leq i \leq q} \{y_i + i\}$$

$$= \min_{1 \leq i \leq q} \{(x^* + 1 - x_i) + i\}$$

(by 3.b) and we have

$$p(<y_i>) = \alpha * (<x_i>) + 2q - \min_{1\leq i\leq q}\{(x^* - x_i) + i + 1\}$$

$$p(<y_i>) = \alpha * (<x_i>) + 2q - \min_{1\leq i\leq 2q}\{y_i + i\}$$

This completes the proof.

▷ Let us illustrate the theorem and corollary of 3.1, by the following:

Suppose $<x_i> = (3, 2, 2, 1, 1)$, by the theorem 3.1, $\alpha* = 3, p(G_1) = 4, x^* = 3$, $<y_i>$=(1,2,2,3,3,3,2,2,1,1), and by corollary 3.1, $p(G_2) = 11$. Then the graph as shown in Figure 3:

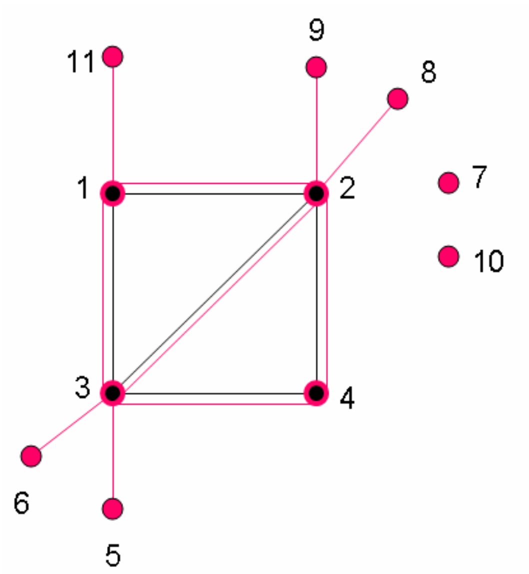



Figure 3

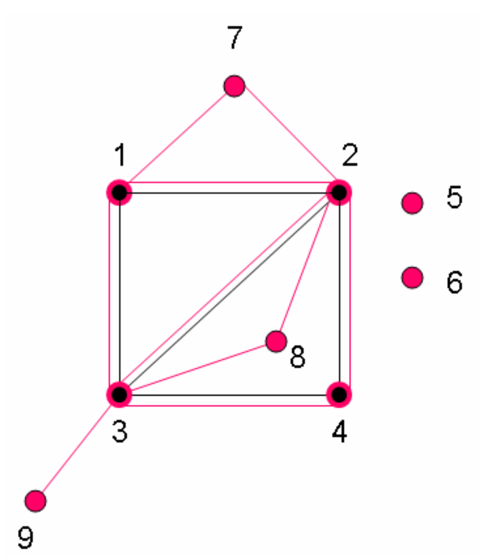



Figure 4

**Theorem 3.2.** *If $(x_1, x_2, \ldots, x_q)$ represents a super edge-magic sequence of a graph G on $'q'$ edges with*

$$\alpha * (<x_i>) = \max_{1\leq i\leq q}\{2x_i + i\} + 1 - q.......(3.g)$$

$$p(<x_i>) = \max_{1\leq i\leq q}\{2x_i + i\} - \min_{1\leq i\leq q}\{x_i + i\} + 1......(3.h)$$

*Then* $(x_* + 1 - x_q, x_* + 1 - x_{q-1}, \dots, x^* + 1 - x_2, x^* + 1 - x_1, x_1, x_2, \dots, x_q)$ *represents super edge-magic sequence on 2q edges with same* $\alpha*$*, for* $x^*=$ *max*$\{x_i/1 \leq i \leq q\}$.

*Proof.* Let $y_i = x^* + 1 - x_q - i + 1$, $1 \leq i \leq q$ $y_{q+i} = x_i$ , $1 \leq i \leq q$ The given sequence becomes: $(y_1, y_2, ..., y_q, y_{q+1}, ..., y_{2q})$

$$\max_{1 \leq i \leq q} \{2y_i + i\} = \max_{1 \leq i \leq q} \{2(x^* + 1 - x_{q-i+1} + i\}$$

$$= 2x^* + 2 - \min_{1 \leq i \leq q} \{2x_{q-i+1} + i\}$$

$$\max_{1 \leq i \leq q} \{2y_i + i\} < 2x^* + q......(3.i)$$

Using theorem 3.1, $2x * +q < \alpha * (< x_i >)$ + 2q -1 and By (3.e)

$$\max_{q+1 \leq i \leq 2q} \{2y_i + i\} \leq \alpha * (< x_i >) + 2q - 1......(3.j)$$

By (3.i) and (3.j),

$$\max_{1 \leq i \leq 2q} \{2y_i + i\} = \alpha * (< x_i >) + 2q - 1$$

$$\alpha * (< y_i >) = \max_{1 \leq i \leq 2q} \{2y_i + i\} + 1 - 2q$$

By applying (3.g) $\alpha * (< y_i >) = \alpha * (< xi >)$

This completes the proof.

**Corollary 3.2.** *If* $(x^* + 1 - x_q, x^* + 1 - x_{q-1}, ..., x^* + 1 - x_2, x^* + 1 - x_1, x_1, x_2, ..., x_q)$ *represents super edge-magic sequence on 2q edges satisfying the conditions in theorem 3.2 then the number of vertices is given by*

$$\alpha * (< x_i >) + 2q - \min_{1 \leq i \leq 2q} \{y_i + i\}$$

.

*Proof.* The sequence $< y_i >$ and other details are followed by theorem 3.2.

$$\min_{1 \leq i \leq 2q} \{y_i + i\} = \min_{1 \leq i \leq q} \{(x^* + 1 - x_{q-i+1})\}$$

$$= (x * +1) - \max_{1 \leq i \leq q} \{(x_{q-i+1})\}$$

$$p(< yi >) = \max_{1 \leq i \leq 2q} \{2y_i + i\} - \min_{1 \leq i \leq 2q} \{y_i + i\} + 1$$

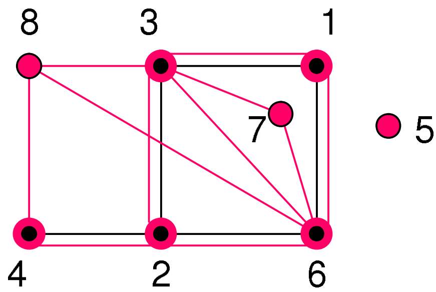



Figure 5

By using (3.h)

$$p(< yi >) = \alpha * (< xi >) + 2q - \min_{1 \le i \le 2q} \{y_i + i\}$$

This completes the proof.

▷**Concrete Example for the theorem and corollary of 3.2:** Suppose $< x_i > =$ (3,2,2,1,1), by using theorem 3.2,$\alpha* = 3$, $p(G_1)$ =4, $x^* = 3$, $< y_i >$=(3,3,2,2,1,3,2,2,1,1), and by corollary 3.2, $p(G_2) = 9$. Then the graph as shown in Figure 4.

**Theorem 3.3.** *If* $(x_1, x_2, \ldots, x_q)$ *represents a super edge-magic sequence with*

$$\alpha * (< x_i >) = \max_{1 \le i \le q} \{2x_i + i\} + 1 - q$$

*and*

$$p(< x_i >) = \max_{1 \le i \le q} \{2x_i + i\} - \min_{1 \le i \le q} \{x_i + i\} + 1$$

*Then* $(\alpha * +q - 1 - x_1, \alpha * +q - 2 - x_2, \ldots, \alpha * -x_q, \lambda, x_1, x_2, \ldots, x_q)$ *represents a super edge-magic sequence on 2q+1 edges with same* $\alpha*$*, choose* $\lambda$ *such that* $1 \le \lambda < q$.

*Proof.* This is an immediate consequence of definition and by applying theorem 3.1.

**Remark 3.1.** Based on the parameter $< x_i >$, q, $\alpha*$, At least one $\lambda$ such that $1 \le \lambda < q$ would give SEMG.

▷ Let us illustrate the theorem and corollary of 3.3 as follows: $< x_i > =$ (2,1,2,2,1), $\alpha*$= 4, $p(G_1)$= 6, $< y_i > =$ (6,6,4,3,3,3,2,1,2,2,1),$\lambda = 3$, $p(G_2) = 8$. Figure 5 shows the graph.

**Remark 3.2.** Theorems from 3.1 to 3.3 have the same property that the sequence $< x_i >$ and $< y_i >$ have same $\alpha*$. Each sequence gives one super edge-magic graph say $G_1, G_2$ respectively then the graph $G_2$ contains $G_1$ always. $G_1$ indicated by block color and $G_2$ indicated by pink color.

**Theorem 3.4.** *If $(x_1, x_2, \ldots, x_q)$ represents a super edge-magic sequence of a graph G on "q" edges with*

$$\alpha * (< x_i >) = \max_{1 \leq i \leq q} \{2x_i + i\} + 1 - q$$

$$p(< x_i >) = \max_{1 \leq i \leq q} \{2x_i + i\} - \min_{1 \leq i \leq q} \{x_i + i\} + 1$$

*Then $(2x_1 + 1, 2x_1, 2x_2 + 1, 2x_2, ..., 2x_q + 1, 2x_q)$ represents super edge-magic sequence of a graph H such that α∗(H)=2α∗(G) and p(H) =2p(G).*

*Proof.* This is an immediate consequence on modification of $< x_i >$ by definition.

**Remark 3.3.** $\alpha*$ of H is twice number of $\alpha*$ of G, so that the structure of the graph G is embedded in H and also the labeling of G is exactly doubled.

▷Let us illustrate the theorem 3.4.by the following: In the succeeding figures the color green indicates the graph G and blue indicates H.

• If G has one connected component then the corresponding H as follows: $< x_i >$ = (4,4,2,1,2,3,1,3,1), $\alpha*$(G)=6, p(G)=10, q(G)=9. The sequence for H = (9,8,9,8,5,4,3,2,5,4,7,6,3,2,7,6,3,2), p(H)=20, q(H)=18, $\alpha*$(H)=12. Then the graph as shown in Figure 6

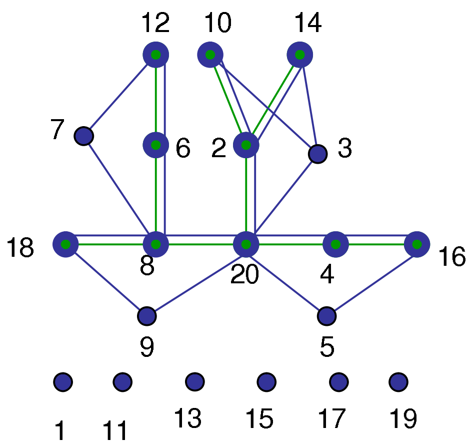



Figure 6

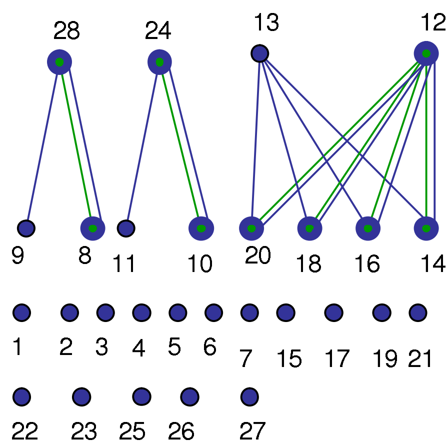



Figure 7

• If G has more than one connected components the corresponding H as follows: $< x_i >$ =(4,5,6,6,6,6) $\alpha*$(G)=13, p(G)=14, q(G) =6. The sequence for H=(9,8,11,10,13,12,13,12,13,12,13,12), $\alpha*$(H)=26,p(H)=28,q(H)=12. Then the graph as shown in Figure 7

**Proposition 3.1.** *If any super edge-magic sequence does not contain the element $'1'$, then (m-1) number of deficiency can be reduced by subtracting (m-1) in each element of that sequence, where m is minimum element of the given super edge-magic sequence.*

*Proof.* This is an immediate consequence of theorem 3.4.

## 4. Monotonic Sequences and their Behavior in Super Edge-Magic Graph

**Proposition 4.1.** *If the sequence $< x_i >$, $1 \leq i \leq q$ defines a super edge-magic graph with $x_1 \geq x_2 \geq x_3 \geq \cdots \geq x_q (= 1)$ then the feasible range of $\alpha*$ is $x_q + 2 \leq \alpha* \leq x_1 + 2$.*

The range of $\alpha*$ is $(x_q + 2, x_1 + 2)$ but all $\alpha*$ need not give super edge-magic graph. To find $\alpha*$ which will give super edge-magic graph from the following.

**Proposition 4.2.** *Let $< x_i >$, $1 \leq i \leq q$ be super edge-magic sequence such that$x_1 \geq x_2 \geq x_3 \geq \cdots \geq x_q$ with $x_q = 1$,*

$$\alpha = \max_{1 \leq i \leq q} \{2x_i + i\} and \beta = \min_{1 \leq i \leq q} \{x_i + i\}$$

*. Then the number of super edge-magic graph is $(q + 1) - (\alpha - \beta)$ which is denoted by $'r'$. Moreover, the value of $\alpha*$ is $\alpha - q + j$, $1 \leq j \leq r$ and the corresponding value of p is at least $\alpha * -\beta + q$.*

**Definition 4.1.** Let $< x_i >$, $1 \leq i \leq q$ be super edge-magic sequence such that $x_1 \leq x_2 \leq x_3 \leq \ldots, \leq x_q$ then number of digits appeared in the sequence $< x_i >$,$1 \leq i \leq q$ is said to be "$order of the sequence$" and denoted by $'n'$.

**Proposition 4.3.** *Let $< x_i >$,$1 \leq i \leq q$ be super edge-magic sequence such that $x_1 \leq x_2 \leq x_3 \leq \ldots, \leq x_q$ with $x_1$ =1.Then $\alpha* = 2x_q + 1$, p=$2x_q + q - 1$ must be super edge-magic graph with deficiency[13] is n-1.*

## 5. Conclusion

The relevance of this paper is two fold. First, we introduced definition of SEMS and construction method for SEMG from SEMS. In a consequent step, the limitations and upshots of SEMS were also discussed. Second, Fabrication of New SEMS and behavior of monotonic sequences of super edge-magic graph were discussed.

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