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INTRODUCTION

We had the great honor of of 3rd International Conference on Pioneer and Innovative Studies ICPIIS 2025. It was truly a great pleasure for us to greet a lot of participants from many different countries attending ICPIIS 2025! We firmly believe that the conference will become an important international event in the field of cross-industry discussion about innovations in Academic Studies.

Three cooperating organizations supported the two-day conference. There were 156 papers accepted for presentation at ICPIIS 2025, contributed from different countries. We had plenary speeches and several well-known scientists and experts, to give invited talks at different sessions.

The purpose of ICPIIS 2025 was to provide a forum for the participants to report and review innovative ideas, with up-to-date progress and developments, and discuss novel approaches to the application in the field of their own research areas and discuss challenges of doing science.

We sincerely hope that the exchange of ideas on doing research, science and improving education will help the participants, and international cooperation sharing the common interest will be enhanced.

On behalf the Organization Committee of ICPIIS 2025, we would like to heartily thank our cooperating organizations for all they have done for the conference. We would also like to thank the authors for their contribution to the proceedings; the participants and friends of ICPIIS 2025, for their interest and efforts in helping us to make the conference possible; and the Editorial boards for their effective work and valuable advice, especially the ICPIIS 2025 secretariat and the ICPIIS 2025 staff, for their tireless efforts and outstanding services in preparing the conference and publishing the Proceedings.

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The First Zagreb Index and First Leap Zagreb Index of Fibonacci Cubes

Özge Çolakoglu^{*1}

¹Department of Mathematics, Faculty of Science, Mersin University, Turkey

^{*}(ozgeclkg@gmail.com) Email of the corresponding author

Abstract – Fibonacci cubes derived from Fibonacci numbers represent chemical structures as well as are used in networks. Chemical graph theory uses topological indices to predict chemical structures' physical, chemical, and biological properties without experimentation. Topological indices are scalar descriptors of the chemical molecule represented by a ϑ graph. In this study, the first Zagreb index which is degree based and first leap Zagreb index which is distance based of Fibonacci cubes are obtained.

Keywords – Graph Theory, Topological Index, Fibonacci Cubes, First Zagreb Index, First Leap Zagreb Index.

I. INTRODUCTION

Graph theory, emerged in 1736 by being used to solve a problem, is a field of Discrete Mathematics. Graph theory has brought solutions to many problems in various science areas. The Boolean cube or hypercube, cosmic cube, n -cube, or binary n -cube are popular interconnection schemes for multicomputer. Fibonacci cubes are introduced as an alternative model to these. Since sub graph of the hypercube and also an upper graph of other structures are Fibonacci cubes, they can find applications in fault-tolerant computing. In addition, the common system communication principles of Fibonacci cubes can be applied efficiently. Although the Fibonacci cubes appear to be structurally disadvantaged compared to the hypercube, information about semi-regular networks has been found to be useful for fault-tolerant applications [1].

Representations of Fibonacci cubes are seen in chemistry. Since a Fibonacci is a chain with three hexagonal, Fibonacci cubes are resonance graph of a Fibonacci with n hexagons. In addition, they are the plane bipartite graphs of resonance graphs [2]. Chemical graph theory is the field of study with the graph theory of chemical structures. It focuses on topological indices. The topological index is the numerical value obtained using various features such as distance and degree of the graph representation of the chemical structure [3]. Topological indices are used to predict the physicochemical and bioactivity properties of chemical structures. The first-known index to have an application is the Wiener index [4]. Among the topological indices, the most studied indices are degree-dependent indices.

Klavzar and Mollard studied the Wiener indices and Hosoya polynomials of Fibonacci cubes [5]. Klavzar and Rho expressed the Wiener index of generalized Fibonacci cubes [6]. Egecioğlu et al. obtained the Mostar indices of Fibonacci cubes [7]. Egecioğlu et al. determined the irregularity polynomials of Fibonacci cubes [8]. Alizadeh et al. studied on the irregularity of Fibonacci cubes [9].

This paper is focused on Fibonacci cubes. The first Zagreb and the first leap Zagreb indices of Fibonacci cubes are obtained.

II. PRELIMINARIES

Let ϑ be a graph with vertex set $V(\vartheta)$ and edge set $E(\vartheta)$. The cardinality of $V(\vartheta)$ (order) is defined as n . The cardinality of $E(\vartheta)$ (size) is defined as m . $N_u(\vartheta)$ is the set of vertices that neighbour to u [10].

Lemma 2.1. [10] If ϑ is graph with size m , then $\sum_{u \in V(\vartheta)} d_u = 2m$.

Definition 2.2. [7] The k -dimensional hypercube has vertex set which is set of all binary strings of length k . Let two vertices $\gamma_1\gamma_2 \dots \gamma_k$ and $\gamma_1'\gamma_2' \dots \gamma_k'$ of the k -dimensional hypercube where $\gamma_i \in \{0,1\}$ for $i = 1, \dots, k$. The vertices $\gamma_1\gamma_2 \dots \gamma_k$ and $\gamma_1'\gamma_2' \dots \gamma_k'$ are adjacent if and only if γ_i and γ_i' differ in exactly one $i = 1, \dots, k$.

Definition 2.3. [1] The k -dimensional Fibonacci cubes, Γ_k are the subgraph of k -dimensional hypercubes. If $\gamma_1\gamma_2 \dots \gamma_k$ is a vertex of Fibonacci cube, then $\gamma_i \cdot \gamma_{i+1} = 0$ for $i = 1, \dots, k-1$ and $\gamma_1 \cdot \gamma_2 = 0$.

The Fibonacci cubes have

$$|V(\Gamma_k)| = F_{k+2} \quad (1)$$

and

$$|E(\Gamma_k)| = \frac{kF_{k+1} + 2(k+1)F_k}{5} \quad (2)$$

where $F_0 = 0, F_1 = 1$ and $F_{k+2} = F_{k+1} + F_k$ for $k \geq 1$ [1, 9].

Eğecioğlu et al. [8] defined symbolically decomposition as

$$\Gamma_k = 0\Gamma_{k-1} + 10\Gamma_{k-2} \quad (3)$$

Alizadeh et al. [9] defined the following subsets of vertices of Γ_k :

$$A_k = \{00\gamma_3\gamma_4 \dots \gamma_k : \gamma_i \in \{0,1\}, i = 3, \dots, k\} \quad (4)$$

$$B_k = \{10\gamma_3\gamma_4 \dots \gamma_k : \gamma_i \in \{0,1\}, i = 3, \dots, k\} \quad (5)$$

$$C_k = \{010\gamma_4\gamma_5 \dots \gamma_k : \gamma_i \in \{0,1\}, i = 4, \dots, k\} \quad (6)$$

$V(\Gamma_k) = A_k \cup B_k \cup C_k$ and the sets A_k, B_k, C_k are disjoint. Moreover, the subgraphs $\langle A_k \rangle, \langle B_k \rangle, \langle C_k \rangle$ are isomorphic to $\Gamma_{k-2}, \Gamma_{k-2}$ and Γ_{k-3} , respectively. Then, the vertices in A_k set are neighbour the vertices in B_k and C_k . The vertices in B_k is not neighbour the vertices in C_k [9].

III. THE FIRST ZAGREB INDEX OF FIBONACCI CUBES

One of the most used degree-based indices is the first Zagreb index. The first Zagreb index introduced by Gutman and Trinajstić [11] as

$$M_1(\vartheta) = \sum_{uv \in E(\vartheta)} (d_u + d_v) \quad (7)$$

They used to find the energy of the molecules [11]. There are many studies related with the first Zagreb index (for more detail, see [12-19]).

Theorem 3.1. Let Γ_k be k -dimensional Fibonacci cubes. Then, for $k \geq 2$,

$$M_1(\Gamma_k) = M_1(\Gamma_{k-1}) + M_1(\Gamma_{k-2}) + 8|E(\Gamma_{k-2})| + 2|V(\Gamma_{k-2})| + 2|V(\Gamma_{k-3})|$$

Proof. By direct computation, $M_1(\Gamma_0) = 0$ and $M_1(\Gamma_1) = 2$. Figure 1 is Γ_5 graph which is equal to $0\Gamma_4 + 10\Gamma_3$.

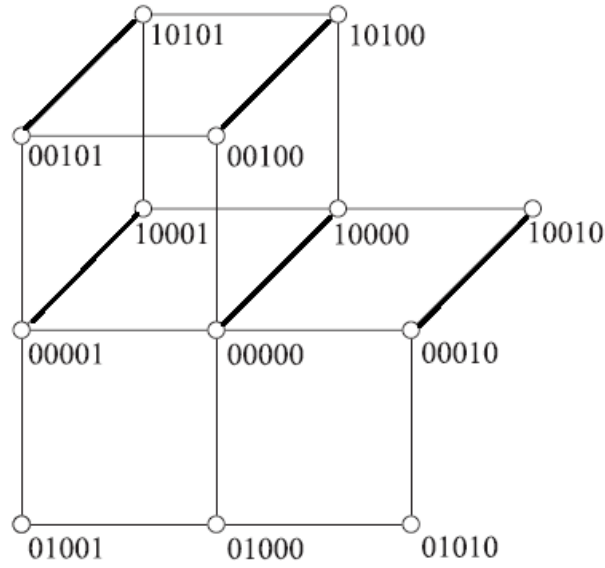


Fig. 1. The Γ_5 graph ($\Gamma_5 = 0\Gamma_4 + 10\Gamma_3$)

Assume that the vertex and edge sets of Γ_k are decomposition as

$$V(\Gamma_k) = V(\Gamma_{k-1}) \cup V(\Gamma_{k-2}) \quad (8)$$

where $V(\Gamma_{k-1}) = A_k \cup C_k$, $V(\Gamma_{k-2}) = B_k$

$$E(\Gamma_k) = E(\Gamma_{k-1}) \cup E(\Gamma_{k-2}) \cup E' \quad (9)$$

where $E(\Gamma_{k-1}) = \{uv \in E(\Gamma_k) | u \in A_k, v \in C_k\} \cup \{uv \in E(\Gamma_k) | u, v \in A_k\} \cup \{uv \in E(\Gamma_k) | u, v \in C_k\}$,
 $E(\Gamma_{k-2}) = \{uv \in E(\Gamma_k) | u, v \in B_k\}$, and $E' = \{uv \in E(\Gamma_k) | u \in A_k, v \in B_k\}$

where A_k, B_k, C_k are given in Equations (4), (5), and (6), respectively.

It is clear that

$$|E(\Gamma_k)| = |E(\Gamma_{k-1})| + |E(\Gamma_{k-2})| + |E'| \text{ where } |E'| = |V(\Gamma_{k-2})| = F_n$$

All vertex of the $\langle B_k \rangle$ subgraph in Γ_k to the vertices of the $\langle A_k \rangle$ subgraph in Γ_k and are connected by edges.

The following equation can be written by Equations (7) and (9):

$$\begin{aligned} M_1(\Gamma_k) = & \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u \in A_k, v \in C_k}} (d_u + 1 + d_v) + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in A_k}} (d_u + 1 + d_v + 1) \\ & + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in C_k}} (d_u + d_v) \\ & + \sum_{\substack{uv \in E(\Gamma_{k-2}) \\ u, v \in B_k}} (d_u + 1 + d_v + 1) + \sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k}} (d_u + 1 + d_v + 1) \end{aligned}$$

or

$$\begin{aligned}
M_1(\Gamma_k) = & \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u \in A_k, v \in C_k}} (d_u + d_v) + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u \in A_k, v \in C_k}} 1 + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in A_k}} (d_u + d_v) + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in A_k}} 2 \\
& + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in C_k}} (d_u + d_v) \\
& + \sum_{\substack{uv \in E(\Gamma_{k-2}) \\ u, v \in B_k}} (d_u + d_v) + \sum_{\substack{uv \in E(\Gamma_{k-2}) \\ u, v \in B_k}} 2 + \sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k}} (d_u + d_v) + \sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k}} 2
\end{aligned} \tag{10}$$

Note 1. Since $\langle A_k \rangle$ and $\langle B_k \rangle$ are isomorphic to Γ_{k-2} ,

i. $\sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in A_k}}$ is equal to $|E(\Gamma_{k-2})|$.

ii. $\sum_{\substack{uv \in E(\Gamma_{k-2}) \\ u, v \in B_k}}$ is equal to $|E(\Gamma_{k-2})|$.

Note 2. Since $\langle C_k \rangle$ is isomorphic to Γ_{k-3} , $\sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u \in A_k, v \in C_k}}$ is equal to $|V(\Gamma_{k-3})| = F_{n-1}$.

From Equations (7) and (10), and Notes 1-2, it can be written

$$\begin{aligned}
M_1(\Gamma_k) = & M_1(\Gamma_{k-1}) + |V(\Gamma_{k-3})| + 2|E(\Gamma_{k-2})| + M_1(\Gamma_{k-2}) + 2|E(\Gamma_{k-2})| + \sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k}} (d_u + d_v) \\
& + 2|V(\Gamma_{k-2})|
\end{aligned} \tag{11}$$

Lemma 3.2. For $uv \in E'$ and $v \in A_k, u \in B_k$ in Γ_k ,

$$\sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k}} (d_{u_{\Gamma_{k-1}}} + d_{v_{\Gamma_{k-2}}}) = 4|E(\Gamma_{k-2})| + |V(\Gamma_{k-3})|.$$

Proof. Let $x \in V(\Gamma_{k-3})$ and $v \in V(\Gamma_{k-2})$ in $xv \in E(\Gamma_{k-1})$. For $v \in A_k, u \in B_k$,

i. If $v \in N(V(\Gamma_{k-3}))$, then

$$d_{v_{\Gamma_{k-1}}} = d_{u_{\Gamma_{k-2}}} + 1 \tag{12}$$

ii. If $v \notin N(V(\Gamma_{k-3}))$, then

$$d_{v_{\Gamma_{k-1}}} = d_{u_{\Gamma_{k-2}}} \tag{13}$$

From Equations (12)-(13), it can be written

$$\begin{aligned}
& \sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k}} (d_{u_{\Gamma_{k-1}}} + d_{v_{\Gamma_{k-2}}}) \\
&= \sum_{\substack{v \in A_k, u \in B_k \\ v \in N(C_k)}} (d_{u_{\Gamma_{k-2}}} + 1 + d_{u_{\Gamma_{k-2}}}) \\
&\quad + \sum_{\substack{v \in A_k, u \in B_k \\ v \notin N(C_k)}} (d_{u_{\Gamma_{k-2}}} + d_{u_{\Gamma_{k-2}}}) \\
&= \sum_{\substack{v \in A_k, u \in B_k \\ v \in N(C_k)}} 1 + \sum_{u \in B_k} 2d_{u_{\Gamma_{k-2}}} \\
&= \sum_{\substack{v \in A_k, u \in B_k \\ v \in N(C_k)}} (d_{u_{\Gamma_{k-2}}} + 1 + d_{u_{\Gamma_{k-2}}}) + \sum_{\substack{v \in A_k, u \in B_k \\ v \notin N(C_k)}} (d_{u_{\Gamma_{k-2}}} + d_{u_{\Gamma_{k-2}}}) \\
&= \sum_{\substack{v \in A_k, u \in B_k \\ v \in N(C_k)}} 1 + \sum_{u \in B_k} 2d_{u_{\Gamma_{k-2}}} \\
&= 2 \sum_{u \in B_k} d_{u_{\Gamma_{k-2}}} + |V(\Gamma_{k-3})|.
\end{aligned}$$

From Lemma 2.1,

$$\sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k}} (d_{u_{\Gamma_{k-1}}} + d_{v_{\Gamma_{k-2}}}) = 4|E(\Gamma_{k-2})| + |V(\Gamma_{k-3})|.$$

From Equation (11), Equation (1), and Lemma 3.2, the proof is completed.

Corollary 3.3. If Γ_k is k -dimensional Fibonacci cubes, then, for $k \geq 2$,

$$M_1(\Gamma_k) = M_1(\Gamma_{k-1}) + M_1(\Gamma_{k-2}) + \frac{(8k - 14)F_{k-1} + 16(k - 1)F_{k-2} + 10F_k}{5}$$

Proof. From Theorem 3.1 and Equations (1) and (2), the proof is completed.

IV. THE FIRST LEAP ZAGREB INDEX OF FIBONACCI CUBES

In 2007, the first leap Zagreb indices of graph ϑ are introduced by Naji et al. as

$$LM_1(\vartheta) = \sum_{uv \in E(\vartheta)} (d'_u + d'_v) \tag{14}$$

where $d'_u = |\{u \in V: d(u, v) = 2\}|$ [20]. The first leap Zagreb index has been found to be a very good predictive index for many properties such as the boiling point of octane isomers [21]. Manjunatha et al. examined the first leap Zagreb index of a Mycielskian graph [22]. Chidambaram et al. studied leap Zagreb indices of bridge and chain graphs and chemical applications [23]. It was studied leap Zagreb indices of some networks [24], of central of a graph [25], of graph operations [26].

Lemma 4.1. ([27, 28]) If ϑ is a graph with k order and m size, then $\sum_{u \in V(\vartheta)} d'_u \leq M_1(\vartheta) - 2m$. ϑ is a $\{C_3, C_4\}$ -free graph if and only if it holds the equality.

Theorem 4.2. Let Γ_k be k -dimensional Fibonacci cubes. Then, for $k \geq 3$,

$$LM_1(\Gamma_k) \leq LM_1(\Gamma_{k-1}) + LM_1(\Gamma_{k-2}) + 3M_1(\Gamma_{k-2}) + 4|E(\Gamma_{k-2})| + 6|E(\Gamma_{k-3})| + |V(\Gamma_{k-4})| \\ + |V(\Gamma_{k-3})| + |V(\Gamma_{k-1})|$$

Proof. Since all the vertices $V(\Gamma_{k-2})$ in $V(\Gamma_k)$ are joined by one edge with the $V(\Gamma_{k-2})$ vertices in $V(\Gamma_{k-1})$, the followings are written:

- i. If $u \in A_k$, then $d'_{u\Gamma_k} = d'_{u\Gamma_{k-1}} + d_{x\Gamma_{k-2}}$, for $x \in B_k$, $xu \in E'$ and $x \in N(A_k)$.
- ii. If $u \in B_k$, then $d'_{u\Gamma_k} = d'_{u\Gamma_{k-2}} + d_{x\Gamma_{k-1}}$, for $x \in A_k$ and $x \in N(B_k)$.
- iii. If $u \in C_k$, then $d'_{u\Gamma_k} = d'_{u\Gamma_{k-1}} + 1$.

From Equations (9) and (14), and also above (i), (ii), and (iii), the following equation is obtained:

$$LM_1(\Gamma_k) = \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in A_k, x, y \in B_k}} (d'_{u\Gamma_{k-1}} + d_{x\Gamma_{k-2}} + d'_{v\Gamma_{k-1}} + d_{y\Gamma_{k-2}}) \\ + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u \in A_k, v \in C_k, x \in B_k}} (d'_{u\Gamma_{k-1}} + d_{x\Gamma_{k-2}} + d'_{v\Gamma_{k-1}} + 1) \\ + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in C_k}} (d'_{u\Gamma_{k-1}} + 1 + d'_{v\Gamma_{k-1}} + 1) \\ + \sum_{\substack{uv \in E(\Gamma_{k-2}) \\ u, v \in B_k, x, y \in A_k \\ xy \in E(\Gamma_{k-1})}} (d'_{u\Gamma_{k-2}} + d_{x\Gamma_{k-1}} + d'_{v\Gamma_{k-2}} + d_{y\Gamma_{k-1}}) \\ + \sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k \\ x \in B_k, x \in N(A_k), y \in A_k}} (d'_{u\Gamma_{k-1}} + d_{x\Gamma_{k-2}} + d'_{v\Gamma_{k-2}} + d_{y\Gamma_{k-1}})$$

or

$$LM_1(\Gamma_k) = \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in A_k}} (d'_{u\Gamma_{k-1}} + d'_{v\Gamma_{k-1}}) + \sum_{\substack{xy \in E(\Gamma_{k-2}) \\ x, y \in B_k}} (d_{x\Gamma_{k-2}} + d_{y\Gamma_{k-2}}) \\ + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u \in A_k, v \in C_k}} (d'_{u\Gamma_{k-1}} + d'_{v\Gamma_{k-1}}) \\ + \sum_{x \in B_k} d_{x\Gamma_{k-2}} + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u \in A_k, v \in C_k}} 1 + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in C_k}} (d'_{u\Gamma_{k-1}} + d'_{v\Gamma_{k-1}}) + \sum_{\substack{uv \in E(\Gamma_{k-1}) \\ u, v \in C_k}} 2$$

$$\begin{aligned}
& + \sum_{\substack{uv \in E(\Gamma_{k-2}) \\ u, v \in B_k}} (d'_{u_{\Gamma_{k-2}}} + d'_{v_{\Gamma_{k-2}}}) + \sum_{\substack{xy \in E(\Gamma_{k-1}) \\ x, y \in A_k}} (d_{x_{\Gamma_{k-1}}} + d_{y_{\Gamma_{k-1}}}) \\
& + \sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k}} (d'_{u_{\Gamma_{k-1}}} + d'_{v_{\Gamma_{k-2}}}) \\
& + \sum_{\substack{uv \in E' \\ v = y \in A_k, x = u \in B_k}} (d_{x_{\Gamma_{k-2}}} + d_{y_{\Gamma_{k-1}}})
\end{aligned}$$

From Note 1, Note 2 and Equations (7) and (9), Lemma 2.1, the following equation is written:

$$\begin{aligned}
LM_1(\Gamma_k) &= LM_1(\Gamma_{k-1}) + LM_1(\Gamma_{k-2}) + M_1(\Gamma_{k-2}) + 2|E(\Gamma_{k-2})| + |V(\Gamma_{k-3})| \\
&+ 2|E(\Gamma_{k-3})| + \\
&+ \sum_{\substack{xy \in E(\Gamma_{k-1}) \\ x, y \in A_k}} (d_{x_{\Gamma_{k-1}}} + d_{y_{\Gamma_{k-1}}}) + \sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k}} (d'_{u_{\Gamma_{k-1}}} + d'_{v_{\Gamma_{k-2}}}) \\
&+ \sum_{\substack{uv \in E' \\ v = y \in A_k, x = u \in B_k}} (d_{x_{\Gamma_{k-2}}} + d_{y_{\Gamma_{k-1}}})
\end{aligned} \tag{15}$$

Lemma 4.3. For $uv \in E'$ and $v \in A_k, u \in B_k$ in Γ_k ,

$$\sum_{\substack{uv \in E' \\ v \in A_k, u \in B_k}} (d'_{u_{\Gamma_{k-1}}} + d'_{v_{\Gamma_{k-2}}}) \leq M_1(\Gamma_{k-2}) - 2|E(\Gamma_{k-2})| + 2|E(\Gamma_{k-3})| + |V(\Gamma_{k-1})| - |V(\Gamma_{k-3})|$$

Proof. Let $u \in A_k$ and $v \in V(\Gamma_{k-2})$ in $uv \in E(\Gamma_{k-1})$,

i. If $u \in N(V(\Gamma_{k-3}))$ and $x \in V(\Gamma_{k-3})$, then

$$d'_{u_{\Gamma_{k-1}}} = d'_{v_{\Gamma_{k-2}}} + d_{x_{\Gamma_{k-3}}} \tag{16}$$

ii. If $u \notin N(V(\Gamma_{k-3}))$, then

$$d'_{u_{\Gamma_{k-1}}} = d'_{v_{\Gamma_{k-2}}} + 1 \tag{17}$$

From Equations (16)-(17), it can be written

$$\begin{aligned}
\sum_{\substack{uv \in E' \\ u \in A_k, v \in B_k}} (d'_{u_{\Gamma_{k-1}}} + d'_{v_{\Gamma_{k-2}}}) &= \sum_{\substack{uv \in E', v \in B_k \\ x \in V(\Gamma_{k-3})}} (d'_{v_{\Gamma_{k-2}}} + d_{x_{\Gamma_{k-3}}} + d'_{v_{\Gamma_{k-2}}}) \\
&\quad + \sum_{\substack{uv \in E', v \in B_k \\ u \notin N(V(\Gamma_{k-3}))}} (d'_{v_{\Gamma_{k-2}}} + 1 + d'_{v_{\Gamma_{k-2}}}) \\
&= \sum_{v \in B_k} 2d'_{u_{\Gamma_{k-2}}} + \sum_{\substack{uv \in E', v \in B_k \\ u \notin N(V(\Gamma_{k-3}))}} 1 + \sum_{\substack{x \in B_k \\ x \in V(\Gamma_{k-3})}} d_{x_{\Gamma_{k-3}}}
\end{aligned}$$

From Lemma 4.1,

$$\sum_{\substack{uv \in E' \\ u \in A_k, v \in B_k}} (d'_{u_{\Gamma_{k-1}}} + d'_{v_{\Gamma_{k-2}}}) \leq M_1(\Gamma_{k-2}) - 2|E(\Gamma_{k-2})| + 2|E(\Gamma_{k-3})| + |V(\Gamma_{k-1})| - |V(\Gamma_{k-3})|$$

Lemma 4.4. For $xy \in E(\Gamma_{k-1})$ and $x, y \in A_k$,

$$\sum_{\substack{xy \in E(\Gamma_{k-1}) \\ x, y \in A_k}} (d_{x_{\Gamma_{k-1}}} + d_{y_{\Gamma_{k-1}}}) = M_1(\Gamma_{k-2}) + 2|E(\Gamma_{k-3})| + |V(\Gamma_{k-4})|$$

Proof. From Equations (12)-(13),

$$\begin{aligned}
\sum_{\substack{xy \in E(\Gamma_{k-1}) \\ x, y \in A_k}} (d_{x_{\Gamma_{k-1}}} + d_{y_{\Gamma_{k-1}}}) &= \sum_{\substack{sl \in B_k \\ x, y \in A_k \\ x, y \in N(C_k)}} (d_{s_{\Gamma_{k-2}}} + d_{l_{\Gamma_{k-2}}} + 2) + \sum_{\substack{s, l \in B_k \\ x, y \in A_k \\ x \in N(C_k)}} (d_{s_{\Gamma_{k-2}}} + d_{l_{\Gamma_{k-2}}} + 1) \\
&\quad + \sum_{\substack{sl \in B_k \\ x, y \in A_k \\ x, y \notin N(C_k)}} (d_{s_{\Gamma_{k-2}}} + d_{l_{\Gamma_{k-2}}}) \\
&= M_1(\Gamma_{k-2}) + 2|E(\Gamma_{k-3})| + |V(\Gamma_{k-4})|
\end{aligned}$$

Using Lemma 3.2, Lemma 4.3, Lemma 4.4 in Equation (15), the following equation is obtained

$$\begin{aligned}
LM_1(\Gamma_k) &\leq LM_1(\Gamma_{k-1}) + LM_1(\Gamma_{k-2}) + 3M_1(\Gamma_{k-2}) + 4|E(\Gamma_{k-2})| + 6|E(\Gamma_{k-3})| + |V(\Gamma_{k-4})| + |V(\Gamma_{k-3})| \\
&\quad + |V(\Gamma_{k-1})|
\end{aligned}$$

Corollary 4.5. If Γ_k is k -dimensional Fibonacci cubes, then, for $k \geq 3$,

$$LM_1(\Gamma_k) \leq LM_1(\Gamma_{k-1}) + LM_1(\Gamma_{k-2}) + 3M_1(\Gamma_{k-2}) \\ + \frac{(14k-21)F_{k-2} + (4k-3)F_{k-1} + 12(k-2)F_{k-3}}{5} + F_{k+1}$$

Proof. From Theorem 4.2 and Equations (1)-(2), the proof is completed.

V. RESULTS AND DISCUSSION

Using the concept of topological indices in chemical graph theory, properties of chemical structures can be predicted without experimentation, saving time and money, and contributing to drug discovery. this, in turn, accelerates computer-aided research with advancing technology. in this study, two topological indices based on both the degree and distance concepts of graphs were studied. the values of the topological indices for fibonacci cube graphs were obtained.

VI. CONCLUSION

Fibonacci cubes, which first emerged as a new network topology in parallel computing, have many advantages over other interconnections in the network topology. In addition, Fibonacci cubes are also used in chemical graph theory. Polycyclic aromatic hydrocarbons and some hydrocarbons in chemistry match exactly with Fibonacci cubes. Topological indices are numerical values of the graph representation of the chemical structure used in QSPR/QSAR studies to predict the properties of a chemical structure. In this study, the first Zagreb and first leap Zagreb indices of Fibonacci cubes are calculated. These results will be used in QSPR/QSAR modelling to predict the properties of chemical structures and will shed light on new drug discoveries.

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Özge Çolakoğlu

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Yüksekokulumuz Yönetim ve Organizasyon Bölümü Öğretim Üyesi Doç. Dr. Nermin KİŞİ'nin "All Sciences Academy Yayınevi"nin düzenleyeceği bilimsel toplantıların düzenleme ve bilim kurullarında görev almasında Yüksekokulumuzca bir sakınca bulunmamaktadır. İş bu belge ilgilinin isteği üzerine tanzim edilmiştir.

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Meslek Yüksekokulu Müdürü

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Adres : BEÜ Çaycuma Meslek Yüksekokulu, 67900, Çaycuma, Zonguldak
Telefon : (0372) 643 66 01 Faks:(0372) 643 66 04
e-Posta : caycumamyo@beun.edu.tr Web : <https://cmyo.beun.edu.tr/>
Kep Adresi : beun@hs03.kep.tr

Bilgi için : Tülay KEÇECİ
Unvanı : İşçi

