# Strongly (1,2)( $\hat{g}$ )* Closed Sets In Bitopological Space

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**ABSTRACT**

In this paper, we study the concept of strongly (1,2)( $\hat{g}$ )* - closed sets and check how they deal with the bitopological spaces and their sub-sets. We also read out how the strongly (1,2)
( $\hat{g}$ )*-closed sets and maps inter-relate with other sets with a change or transformation in their properties.

**Key words:** cl(A), int(A), strongly (1,2)( $\hat{g}$ )*-closed set, (1,2)g-closed set, (1,2)gs-closed set, (1,2)g*-closed set, (1,2)g**-closed set, (1,2)sg*-closed set, (1,2)sg**-closed set, (1,2)( $\hat{g}$ )*-closed set.

## 1. INTRODUCTION

A triple (X, $\tau_1$, $\tau_2$ ), where X is a non-empty set and $\tau_1$ and $\tau_2$ are topologiesmon X is called a bitopological space. A.S. Mashhour [1] defined pro-open and pre-closed sets in 1982. N. Levine [4] introduced the class of (generalized closed sets) g -closed sets in 1970. S. P. Arya and Tour [3] defined gs-closed sets (generalized semi-closed sets) in 1990. M.K.R.S. Veerakumar [9] introduced g*-closed sets in 1996. N. Levine [2] defined semi-open and semi-closed sets in 1963. D. Andrijevic [3] defined semi- pre open sets and semi-pre closed sets in 1986. Pauline Mary Helen. M, Veronica Vijayan, and Ponnuthai Selvarani .S [13] introduced g**-closed sets in 2012. Pauline Mary Helen .M and Monica .P [12] introduced sg**-closed sets in 2013. Veerakumar [14] introduced $\hat{g}$ -closed sets in 1991. Pauline Mary Helen .M and A. Gayathri [15] introduced the class of ( $\hat{g}$ )* sets in 2014. The intention of this paper is to give the basic properties of strongly (1,2)( $\hat{g}$ )*-closed set and how it works in relation with other sets.

## 2. PRELIMINARIES

We see the non-empty bitopological space (X, $\tau_1$, $\tau_2$ ), a subset A of X and an open set U of X. We also see the terms, closure of A i.e. cl(A) and interior of A i.e. int(A).

**Definition 2.1:** Let A be a subset of a bitopological space (X, $\tau_1$, $\tau_2$). The interior of A is defined as the union of all open sets contained in A. It is denoted by **int(A)**.

**Definition 2.2:** Let A be a subset of a bitopological space (X, $\tau_1$, $\tau_2$). The closure of A is defined as the intersection of all closed sets containing A. It is denoted by **cl(A)**.

Clearly, int(A) is open and cl(A) is closed.

$$\mathbf{int(A) \subseteq A \subseteq cl(A)}$$

If A is open, A = int(A).

If A is closed, A = cl(A).

**Definition 2.3:** A subset 'A' of the bitopological space $(X, \tau_1, \tau_2)$ is called

1. a pre-open set [1] if **A** $\subseteq$ **int(cl(A))**
2. a pre-closed set [1] if **cl(int(A))** $\subseteq$ **A**
3. a semi-open set [2] if **A** $\subseteq$ **cl(int(A))**
4. a semi-closed set [2] if **int(cl(A))** $\subseteq$ **A**
5. a semi-pre open set [3] if **A** $\subseteq$ **cl(int(cl(A)))**
6. a semi-pre closed set [3] if **int(cl(int(A)))** $\subseteq$ **A**

**Definition 2.4:** A subset 'A' of a bitopological space $(X, \tau_1, \tau_2)$ is called

1. (1,2)g-closed or generalized closed set [4] if **cl(A)** $\subseteq$ **U** whenever A $\subseteq$ U and U is **open** in $(X, \tau)$.
2. (1,2)gs-closed or generalized semi-closed set [9] if **scl(A)** $\subseteq$ **U** whenever A $\subseteq$ U and U is **open** in $(X, \tau)$.
3. (1,2)g*-closed set [9] if **cl(A)** $\subseteq$ **U** whenever A $\subseteq$ U and U is **g-open** in $(X, \tau)$.
4. (1,2)g**-closed set [13] if **cl(A)** $\subseteq$ **U** whenever A $\subseteq$ U and U is **g*-open** in $(X, \tau)$.
5. (1,2)sg*-closed set [10] if **scl(A)** $\subseteq$ **U** whenever A $\subseteq$ U and U is **g*-open** in $(X, \tau)$.
6. (1,2)sg**-closed set [12] if **scl(A)** $\subseteq$ **U** whenever A $\subseteq$ U and U is **g**-open** in $(X, \tau)$.
7. (1,2)$\hat{g}$ -closed set [14] if **cl(A)** $\subseteq$ **U** whenever A $\subseteq$ U and U is **semi-open** in $(X, \tau)$.
8. (1,2) ( $\hat{g}$ )*-closed set [15] if **cl(A)** $\subseteq$ **U** whenever A $\subseteq$ U and U is **$\hat{g}$ -open** in $(X, \tau)$.

## 3. BASIC PROPERTIES OF STRONGLY ( $\hat{g}$ )*-CLOSED SET IN BITOPOLOGICAL SPACES

**Definition 3.1**:

A subset 'A' of a bitopological space $(X, \tau_1, \tau_2)$ is said to be a strongly (1,2)( $\hat{g}$ )*-closed set, if **$\tau_2$-cl(int(A))** $\subseteq$ **U**, whenever A $\subseteq$ U and U is **$\tau_1$-$\hat{g}$ -open** in X.

**Theorem 3.2:**

Every $\tau_2$-closed set is strongly (1,2)( $\hat{g}$ )* -closed.

**<u>Proof:</u>**

Let $(X, \tau_1, \tau_2)$ be a bitopological space.

And A $\subseteq$ $(X, \tau_1, \tau_2)$ is a $\tau_2$-closed set.

i.e. $\tau_2$-Cl(A) = A.

To prove: A is strongly (1,2)( $\hat{g}$ )*-closed.

Let A $\subseteq$ U and U be $\tau_1$-$\hat{g}$ -open.

Then $\tau_2$-cl(A) $\subseteq$ U.

Also, $\tau_2$-cl(int(A)) $\subseteq$ $\tau_2$-cl(A)

We get, $\tau_2$-cl(int(A)) $\subseteq$ $\tau_2$-cl(A) $\subseteq$ U

i.e. $\tau_2$-cl(int(A)) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$-$\hat{g}$ -open.

∴ A is strongly (1,2)( $\hat{g}$ )*-closed.

**Theorem 3.3:**

Every (1,2)g-closed set is strongly (1,2)( $\hat{g}$ )*-closed.

**Proof:**

Let A be a (1,2)g-closed set.

By the definition 2.4.1,

$\tau_2$ -Cl(A) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ -open in (X, $\tau_1$, $\tau_2$ ).

To prove: A is strongly (1,2)( $\hat{g}$ )*-closed.

Let A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$ -open.

We've, $\tau_2$ -cl(A) $\subseteq$ U

Also, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A)

Then, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(int(A)) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$ -open in (X, $\tau$).

∴ A is strongly (1,2)( $\hat{g}$ )*-closed.

The converse of the above theorem need not be true as shown in the following example.

**Example 3.4:**

Let X = {a, b, c}

$\tau_1$ = {ϕ, X, {a}}

$\tau_1$ -closed sets are X, ϕ, {b, c}

$\tau_2$ = {ϕ, X, {a, b}}

$\tau_2$ -closed sets are X, ϕ, {c}

Strongly (1,2)( $\hat{g}$ )*-closed sets are {a}, {b}, {c}, {a, b}, {b, c}, {a, c}, ϕ, X.

(1,2)g- closed sets are {b}, {c}, {a, b}, {b, c},{a, c}, ϕ, X.

Now, A = {a} is a strongly (1,2)( $\hat{g}$ )*-closed set but not (1,2)g-closed.

Hence, every strongly (1,2)( $\hat{g}$ )*-closed set need not be (1,2)g-closed.

**Theorem 3.5:**

Every (1,2)gs-closed set is strongly (1,2)( $\hat{g}$ )*-closed.

**Proof:**

Let A be a (1,2)gs-closed set.

By the definition 2.4.2,

$\tau_2$ -scl(A) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ -open in (X, $\tau_1$, $\tau_2$ ).

To prove: A is strongly (1,2)( $\hat{g}$ )*-closed.

Let A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$-open.

We've, $\tau_2$ -scl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(A) $\subseteq$ U

Also, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A)

Then, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(int(A)) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$ -open in X.

$\therefore$ A is strongly (1,2)( $\hat{g}$ )*-closed.

The converse of the above theorem need not be true as shown in the following example.

**Example 3.6:**

Let X = {a, b, c}

$\tau_1$ = {$\phi$, X, {a}}

$\tau_1$ -closed sets are X, $\phi$, {b, c}

$\tau_2$ = {$\phi$, X, {a, b}}

$\tau_2$ -closed sets are X, $\phi$, {c}

Strongly (1,2)( $\hat{g}$ )*-closed sets are {a}, {b}, {c}, {a, b}, {b, c}, {a, c}, $\phi$, X.

(1,2)gs- closed sets are {b}, {c}, {a, b}, {b, c},{a, c}, $\phi$, X.

Now, A = {a} is a strongly (1,2)( $\hat{g}$ )*-closed set but not (1,2)gs-closed.

Hence, every strongly (1,2)( $\hat{g}$ )*-closed set need not be (1,2)gs-closed.

**Theorem 3.7:**

Every (1,2)g*-closed set is strongly (1,2)( $\hat{g}$ )*-closed.

**Proof:**

Let A be a (1,2)g*-closed set.

By the definition 2.4.3,

$\tau_2$ -cl(A) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ - g-open in (X, $\tau_1$, $\tau_2$ ).

To prove: A is strongly (1,2)( $\hat{g}$ )*-closed.

Let A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$-open.

We've, $\tau_2$ -scl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(A) $\subseteq$ U

Also, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A)

Then, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(int(A)) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$ -open in X.

$\therefore$ A is strongly (1,2)( $\hat{g}$ )*-closed.

The converse of the above theorem need not be true as shown in the following example.

**Example 3.8:**

Let X = {a, b, c}

$\tau_1$ = {$\phi$, X, {a}}

$\tau_1$ -closed sets are X, $\phi$, {b, c}

$\tau_2$ = {$\phi$, X, {a, b}}

$\tau_2$ -closed sets are X, $\phi$, {c}

Strongly (1,2)( $\hat{g}$ )*-closed sets are {a}, {b}, {c}, {a, b}, {b, c}, {a, c}, $\phi$, X.

(1,2)g*- closed sets are {c}, {b, c}, $\phi$, X.

Now, A = {b} is a strongly (1,2)( $\hat{g}$ )*-closed set but not (1,2)g*-closed.

Hence, every strongly (1,2)( $\hat{g}$ )*-closed set need not be (1,2)g*-closed.

**Theorem 3.9:**

Every (1,2)g**-closed set is strongly (1,2)( $\hat{g}$ )*-closed.

**Proof:**

Let A be a (1,2)g**-closed set.

By the definition 2.4.4,

$\tau_2$ -cl(A) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ -g*-open in (X, $\tau_1$, $\tau_2$).

To prove: A is strongly (1,2)( $\hat{g}$ )*-closed.

Let A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$-open.

We've, $\tau_2$ -cl(A) $\subseteq$ U

Also, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A)

Then, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(int(A)) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$ -open in X.

$\therefore$ A is strongly (1,2)( $\hat{g}$ )*-closed.

The converse of the above theorem need not be true as shown in the following example.

**Example 3.10:**

Let X = {a, b, c}

$\tau_1$ = {$\phi$, X, {a}}

$\tau_1$ -closed sets are X, $\phi$, {b, c}

$\tau_2$ = {$\phi$, X, {a, b}}

$\tau_2$ -closed sets are X, $\phi$, {c}

Strongly (1,2)( $\hat{g}$ )*-closed sets are {a}, {b}, {c}, {a, b}, {b, c}, {a, c}, $\phi$, X.

(1,2)g**- closed sets are {c}, {b, c}, {a, c}, $\phi$, X.

Now, A = {b} is a strongly (1,2)( $\hat{g}$ )*-closed set but not (1,2)g**-closed.

Hence, every strongly (1,2)( $\hat{g}$ )*-closed set need not be (1,2)g**-closed.

**Theorem 3.11:**

Every (1,2)sg*-closed set is strongly (1,2)( $\hat{g}$ )*-closed.

**Proof:**

Let A be a (1,2)sg*-closed set.

By the definition 2.4.5,

$\tau_2$ -scl(A) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ - g-open in (X, $\tau_1$, $\tau_2$).

To prove: A is strongly (1,2)( $\hat{g}$ )*-closed.

Let A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$-open.

We've, $\tau_2$ -scl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(A) $\subseteq$ U

Also, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A)

Then, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(int(A)) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$ -open in X.

$\therefore$ A is strongly (1,2)( $\hat{g}$ )*-closed.

The converse of the above theorem need not be true as shown in the following example.

**Example 3.12:**

Let X = {a, b, c}

$\tau_1$ = {$\phi$, X, {a}}

$\tau_1$ -closed sets are X, $\phi$, {b, c}

$\tau_2$ = {$\phi$, X, {a, b}}

$\tau_2$ -closed sets are X, $\phi$, {c}

Strongly (1,2)( $\hat{g}$ )*-closed sets are {a}, {b}, {c}, {a, b}, {b, c}, {a, c}, $\phi$, X.

(1,2)sg*- closed sets are {b}, {c}, {a, b}, {b, c}, {a, c}, $\phi$, X.

Now, A = {a} is a strongly (1,2)( $\hat{g}$ )*-closed set but not (1,2)sg*-closed.

Hence, every strongly (1,2)( $\hat{g}$ )*-closed set need not be (1,2)sg*-closed.

**Theorem 3.13:**

Every (1,2)sg**-closed set is strongly (1,2)( $\hat{g}$ )*-closed.

**Proof:**

Let A be a (1,2)sg**-closed set.

By the definition 2.4.6,

$\tau_2$ -scl(A) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ -g*-open in (X, $\tau_1$, $\tau_2$ ).

To prove: A is strongly (1,2)( $\hat{g}$ )*-closed.

Let A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$-open.

We've, $\tau_2$ -scl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(A) $\subseteq$ U

Also, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A)

Then, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(int(A)) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$ -open in X.

$\therefore$ A is strongly (1,2)( $\hat{g}$ )*-closed.

The converse of the above theorem need not be true as shown in the following example.

**Example 3.14:**

Let X = {a, b, c}

$\tau_1 = \{\phi, X, \{a\}\}$

$\tau_1$ -closed sets are X, $\phi$, {b, c}

$\tau_2 = \{\phi, X, \{a, b\}\}$

$\tau_2$ -closed sets are X, $\phi$, {c}

Strongly (1,2)( $\hat{g}$ )*-closed sets are {a}, {b}, {c}, {a, b}, {b, c}, {a, c}, $\phi$, X.

(1,2)sg**- closed sets are {c}, {b, c}, $\phi$, X.

Now, A = {b} is a strongly (1,2)( $\hat{g}$ )*-closed set but not (1,2)sg**-closed.

Hence, every strongly (1,2)( $\hat{g}$ )*-closed set need not be (1,2)sg**-closed.

**Theorem 3.15:**

Every (1,2)( $\hat{g}$ )-closed set is strongly (1,2)( $\hat{g}$ )*-closed.

**Proof:**

Let A be a (1,2)( $\hat{g}$ )-closed set.

By the definition 2.4.7,

$\tau_2$ -cl(A) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ - semi-open in (X, $\tau_1$, $\tau_2$ ).

To prove: A is strongly (1,2)( $\hat{g}$ )*-closed.

Let A $\subseteq$ U and U is $\tau_1$ -$\hat{g}$-open.

We've, $\tau_2$ -cl(A) $\subseteq$ U

Also, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A)

Then, $\tau_2$ -cl(int(A)) $\subseteq$ $\tau_2$ -cl(A) $\subseteq$ U

i.e. $\tau_2$ -cl(int(A)) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ - $\hat{g}$ -open in X.

$\therefore$ A is strongly (1,2)( $\hat{g}$ )*-closed.

The converse of the above theorem need not be true as shown in the following example.

**Example 3.16:**

Let X = {a, b, c}

$\tau_1 = \{\phi, X, \{a\}\}$

$\tau_1$ -closed sets are X, $\phi$, {b, c}

$\tau_2 = \{\phi, X, \{a, b\}\}$

$\tau_2$ -closed sets are X, $\phi$, {c}

Strongly (1,2)( $\hat{g}$ )*-closed sets are {a}, {b}, {c}, {a, b}, {b, c}, {a, c}, $\phi$, X.

(1,2)( $\hat{g}$ )- closed sets are {c}, {b, c}, $\phi$, X.

Now, A = {b} is a strongly (1,2)( $\hat{g}$ )*-closed set but not (1,2)( $\hat{g}$ )-closed.

Hence, every strongly (1,2)( $\hat{g}$ )*-closed set need not be (1,2)( $\hat{g}$ )-closed.

**Theorem 3.17:**

Every (1,2)( $\hat{g}$ )*-closed set is strongly (1,2)( $\hat{g}$ )*-closed.

**Proof:**

Let A be a (1,2)( ĝ )*-closed set.

By the definition 2.4.8,

$\tau_2$-cl(A) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$-ĝ -open in (X, $\tau_1$, $\tau_2$).

To prove: A is strongly (1,2)( ĝ )*-closed.

Let A $\subseteq$ U and U is $\tau_1$-ĝ-open.

We've, $\tau_2$-cl(A) $\subseteq$ U

Also, $\tau_2$-cl(int(A)) $\subseteq$ $\tau_2$-cl(A)

Then, $\tau_2$-cl(int(A)) $\subseteq$ $\tau_2$-cl(A) $\subseteq$ U

i.e. $\tau_2$-cl(int(A)) $\subseteq$ U, whenever A $\subseteq$ U and U is $\tau_1$ - ĝ -open in X.

$\therefore$ A is strongly (1,2)( ĝ )*-closed.

The converse of the above theorem need not be true as shown in the following example.

**Example 3.18:**

Let X = {a, b, c}

$\tau_1$ = {ϕ, X, {a}}

$\tau_1$-closed sets are X, ϕ, {b, c}

$\tau_2$ = {ϕ, X, {a, b}}

$\tau_2$-closed sets are X, ϕ, {c}

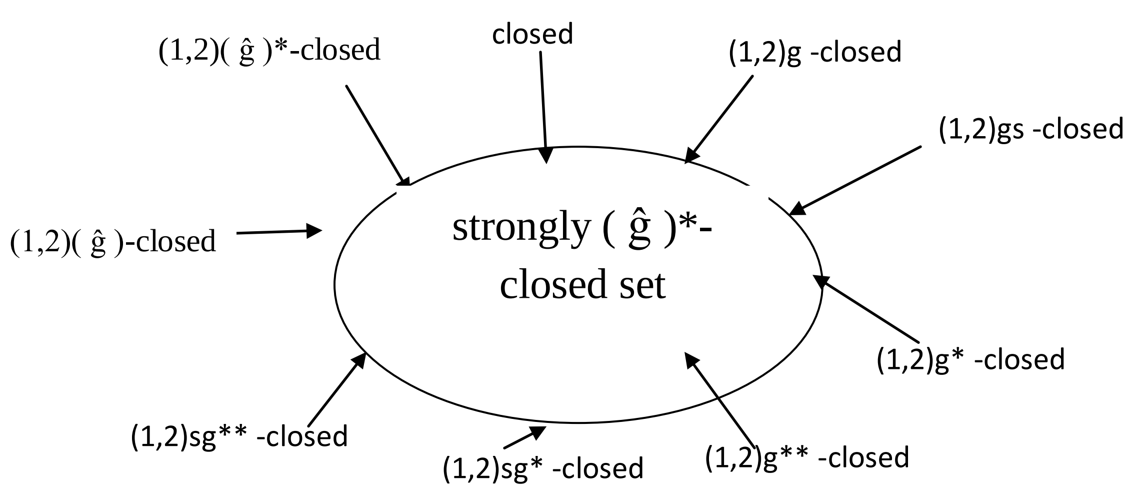
Strongly (1,2)( ĝ )*-closed sets are {a}, {b}, {c}, {a, b}, {b, c}, {a, c}, ϕ, X.

(1,2)( ĝ )*- closed sets are {b}, {c}, {a, b}, {b, c}, {a, c}, ϕ, X.

Now, A = {a} is a strongly (1,2)( ĝ )*-closed set but not (1,2)( ĝ )*-closed.

Hence, every strongly (1,2)( ĝ )*-closed set need not be (1,2)( ĝ )*-closed.

The above results can be represented in the following figure:




Where A→B represents A implies B and B need not imply A.

**CONCLUSION**

Hence, I would like to conclude my paper by giving the properties of strongly (1,2)( ĝ )*-closed set. And also with further results and solutions we can bring in the comparison of strongly (1,2) ( ĝ )*-closed set and function with other sets and functions as well in a given bitopological space.

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