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ON SEMI GENERALIZED STAR b-CLOSED MAP IN TOPOLOGICAL SPACES

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Abstract: In this paper, we introduce a new class of semi generalized star b-closed map and study some of their properties as well as inter relationship with other closed maps.

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Key Words: sg^*b-closed map, b-closed map, gb closed map and rgb closed map

1. Introduction

Different types of closed and open mappings were studied by various researchers. In 1996, Andrijevic introduced new type of set called b - open set. A.A.Omari and M.S.M. Noorani introduced and studied b - closed map.

The aim of this paper is to introduce semi generalized star b - closed map and to continue the study of its relationship with various generalized closed maps. Through out this paper (X, τ) and (Y, σ) represent the non-empty topological spaces on which no separation axioms are assumed, unless otherwise mentioned.

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Let $A \subseteq X$, the closure of A and interior of A will be denoted by $cl(A)$ and $int(A)$ respectively, union of all b - open sets X contained in A is called b - interior of A and it is denoted by $bint(A)$, the intersection of all b - closed sets of X containing A is called b - closure of A and it is denoted by $bcl(A)$.

2. Preliminaries

Definition 2.1. Let A subset A of a topological space (X, τ), is called [1)]

1. a pre-open set [15] if $A \subseteq int(cl(A))$.
2. a semi-open set [12] if $A \subseteq cl(int(A))$.
3. a α -open set [16] if $A \subseteq int(cl(int(A)))$.
4. a α generalized closed set (briefly αg- closed) [13] if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
5. a generalized $*$ closed set (briefly $g^{\star}$-closed)[19] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is $\hat{g}$ open in X.
6. a generalized b- closed set (briefly gb- closed) [1] if $bcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
7. a generalized semi-pre closed set (briefly gsp - closed) [8] if $spcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
8. a generalized pre- closed set (briefly gp- closed) [9] if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
9. a generalized semi- closed set (briefly gs- closed) [8] if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
10. a semi generalized closed set (briefly sg- closed) [5] if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi open in X.
11. a generalized pre regular closed set (briefly gpr-closed) [9] if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is regular open in X.
12. a semi generalized b- closed set (briefly sgb- closed) [10] if $bcl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi open in X.

13. a $\ddot{g}$ - closed set [18] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is sg open in X.

14. a semi generalized star b - closed set (briefly $sg^{\star}b$ - closed)[19] if $bcl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi open in X.

3. On Semi Generalized sg^*b-Closed Map

In this section, we introduce semi generalized star b - closed map ($sg^{\star}b$ - closed) in topological spaces by using the notions of $sg^{\star}b$ - closed sets and study some of their properties.

Definition 3.1. Let X and Y be two topological spaces. A map $f : (X, \tau) \to (Y, \delta)$ is called semi generalized star b - closed (briefly, $sg^{\star}b$ - closed map) if the image of every closed set in X is $sg^{\star}b$ -closed in Y.

Theorem 3.2. *Every closed map is $sg^{\star}b$ - closed but not conversely.*

Proof. Let $f : (X, \tau) \to (Y, \delta)$ is closed map and V be an closed set in X then $f(V)$ is closed in Y. Hence $sg^{\star}b$ - closed in Y. Then f is $sg^{\star}b$ - closed. □

The converse of above theorem need not be true as seen from the following example.

Example 3.3. Consider $X = Y = \{a, b, c\}$, $\tau = \{X, \phi, \{a\}, \{b\}, \{a, b\}\}$ and $\sigma = \{Y, \phi, \{a, b\}\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be defined by $f(a) = b, f(b) = c, f(c) = a$. The map is $sg^{\star}b$ - closed but not closed as the image of $\{b, c\}$ in X is $\{a, c\}$ is not closed in Y.

Theorem 3.4. *Every $\ddot{g}$ - closed map is $sg^{\star}b$ - closed set but not conversely.*

Proof. Let $f : (X, \tau) \to (Y, \sigma)$ is $\ddot{g}$ - closed map and V be an closed set in X then $f(V)$ is closed in Y. Hence $sg^{\star}b$ - closed in Y. Then f is $sg^{\star}b$ - closed. □

The converse of above theorem need not be true as seen from the following example.

Example 3.5. Consider $X = Y = \{a, b, c\}$, $\tau = \{X, \phi, \{a\}, \{c\}, \{a, c\}\}$ and $\sigma = \{Y, \phi, \{a, b\}\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be defined by $f(a) = c, f(b) = b, f(c) = a$. The map is $sg^{\star}b$ - closed but not $\ddot{g}$ - closed as the image of $\{a, b\}$ in X is $\{b, c\}$ is not $\ddot{g}$ - closed in Y.

Theorem 3.6. *Every semi - closed map is $sg^{\star}b$ - closed but not conversely.*

Proof. Let $f : (X, \tau) \to (Y, \sigma)$ be semi-closed map and V be an closed set in X then $f(V)$ is closed in Y. Hence $sg^{\square}b$ - closed in Y. Then f is $sg^{\square}b$ - closed. □

The converse of above theorem need not be true as seen from the following example.

Example 3.7. Consider $X = Y = \{a, b, c\}$, $\tau = \{X, \phi, \{a\}, \{a,\ c\}, \{a, b\}\}$ and $\sigma = \{Y, \phi, \{a, b\}\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be defined by $f(a) = a, f(b) = c, f(c) = b$. The map is $sg^{\square}b$ - closed but not semi - closed as the image of $\{b, c\}$ in X is $\{b, c\}$ is not semi-closed in Y.

Theorem 3.8. *Every α - closed map is $sg^{\square}b$ - closed but not conversely.*

Proof. Let $f : (X, \tau) \to (Y, \delta)$ be semi - closed map and V be an closed set in X then $f(V)$ is closed in Y. Hence $sg^{\square}b$ - closed in Y. Then f is $sg^{\square}b$ - closed. □

The converse of above theorem need not be true as seen from the following example.

Example 3.9. Consider $X = Y = \{a, b, c\}$, $\tau = \{X, \phi, \{c\}\}$ and $\sigma = \{Y, \phi, \{b\}, \{a, b\}\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be defined by $f(a) = a, f(b) = b, f(c) = c$. The map is $sg^{\square}b$ - closed but not α - closed as the image of $\{a, b\}$ in X is $\{a, b\}$ is not α - closed in Y.

Theorem 3.10. *Every pre - closed map is $sg^{\square}b$ - closed but not conversely.*

Proof. Let $f : (X, \tau) \to (Y, \delta)$ pre - closed map and V be an closed set in X then $f(V)$ is closed in Y. Hence $sg^{\square}b$ - closed in Y. Then f is $sg^{\square}b$ - closed. □

The converse of above theorem need not be true as seen from the following example.

Example 3.11. Consider $X = Y = \{a, b, c\}$,$\tau = \{X, \phi, \{c\}, \{b, c\}\}$ and $\sigma = \{Y, \phi, \{b\}, \{a, b\}\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be defined by $f(a) = b, f(b) = a, f(c) = c$. The map is $sg^{\square}b$ -closed but not pre-closed as the image of $\{a, b\}$ in X is $\{a, b\}$ is not pre-closed in Y.

Theorem 3.12. *Every αg - closed map is $sg^{\square}b$ - closed but not conversely.*

Proof. Let $f : (X, \tau) \to (Y, \sigma)$ be αg - closed map and V be an closed set in X then $f(V)$ is closed in Y. Hence $sg^{\square}b$ - closed in Y. Then f is $sg^{\square}b$ - closed. □

The converse of above theorem need not be true as seen from the following example.

Example 3.13. Consider $X = Y = \{a, b, c\}$,$\tau = \{X, \phi, \{b\}, \{a, b\}\}$ and $\sigma = \{Y, \phi, \{a, b\}\}$. Let $f : (X, \tau) \rightarrow (Y, \sigma)$ be defined by $f(a) = c, f(b) = a, f(c) = b$. The map is $sg^{\star}b$ - closed but not αg - closed as the image of $\{c\}$ in X is $\{b\}$ is not αg - closed in Y.

Theorem 3.14. *Every $sg^{\star}b$ - closed map is gsp - closed but not conversely.*

Proof. Let $f : (X, \tau) \rightarrow (Y, \delta)$ be $sg^{\star}b$ closed map and V be an closed set in X then $f(V)$ is closed in Y. Hence gsp - closed in Y. Then f is gsp - closed. □

The converse of above theorem need not be true as seen from the following example.

Example 3.15. Consider $X = Y = \{a, b, c\}$,$\tau = \{X, \phi, \{b\}\}$ and $\sigma = \{Y, \phi, \{a\}, \{c\}, \{a, c\}\}$. Let $f : (X, \tau) \rightarrow (Y, \sigma)$ be defined by $f(a) = b, f(b) = c, f(c) = a$. The map is gsp - closed but not $sg^{\star}b$ - closed as the image of $\{a, c\}$ in X is $\{a, b\}$ is not $sg^{\star}b$ - closed in Y.

Theorem 3.16. *Every $sg^{\star}b$ - closed map is gb - closed but not conversely.*

Proof. Let $f : (X, \tau) \rightarrow (Y, \delta)$ be $sg^{\star}b$ - closed map and V be an closed set in X then $f(V)$ is closed in Y. Hence gb - closed in Y. Then f is gb - closed. □

The converse of above theorem need not be true as seen from the following example.

Example 3.17. Consider $X = Y = \{a, b, c\}$,$\tau = \{X, \phi, \{a\}\}$ and $\sigma = \{Y, \phi, \{a\}, \{a, b\}\}$. Let $f : (X, \tau) \rightarrow (Y, \sigma)$ be defined by $f(a) = b, f(b) = a, f(c) = c$. The map is $sg^{\star}b$ - closed but not gb - closed as the image of $\{b, c\}$ in X is $\{a, c\}$ is not closed in Y.

Theorem 3.18. *Every sg - closed map is $sg^{\star}b$ - closed but not conversely.*

Proof. Let $f : (X, \tau) \rightarrow (Y, \delta)$ be sg - closed map and V be an closed set in X then $f(V)$ is closed in Y. Hence $sg^{\star}b$ - closed in Y. Then f is $sg^{\star}b$ - closed. □

The converse of above theorem need not be true as seen from the following example.

Example 3.19. Consider $X = Y = \{a, b, c\}$,$\tau = \{X, \phi, \{b\}, \{a,\ c\}\}$ and $\sigma = \{Y, \phi, \{b\}, \{a, b\}\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be defined by $f(a) = c, f(b) = b, f(c) = a$. The map is sg -closed but not $sg^{\square}b$ - closed as the image of $\{a, c\}$ in X is $\{a, b\}$ is not closed in Y.

Theorem 3.20. *A map $f : (X, \tau) \to (Y, \sigma)$ is continuous and $sg^{\square}b$ - closed set A is $sg^{\square}b$ -closed set of X then $f(A)$ is $sg^{\square}b$ closed in Y.*

Proof. Let $f(A) \subseteq U$ where U is regular open set in Y. Since f is continuous, $f^{-1}(U)$ is open set containing A. Hence $bcl(A) \subseteq f^{-1}(U)$ (as A is $sg^{\square}b$ - closed). Since f is $sg^{\square}b$ - closed $f(bcl(A)) \subseteq U$ is $sg^{\square}b$ closed set $\Rightarrow bcl(f(bcl(A)) \subseteq U$, Hence $bcl(A) \subseteq U$. So that $f(A)$ is $sg^{\square}b$ - closed set in Y. □

Theorem 3.21. *If a map $f : (X, \tau) \to (Y, \sigma)$ is continuous and closed set and A is $sg^{\square}b$ - closed then $f(A)$ is $sg^{\square}b$ - closed in Y.*

Proof. Let F be a closed set of A then F is $sg^{\square}b$ - closed set. By theorem 3.20 $f(A)$ is $sg^{\square}b$ - closed. Hence $f_A(F) = f(F)$ is $sg^{\square}b$ - closed set of Y. Here f_A is $sg^{\square}b$ - closed and also continuous. □

Theorem 3.22. *If $f : (X, \tau) \to (Y, \sigma)$ is closed map and $g : (Y, \sigma) \to (Z, \eta)$ is $sg^{\square}b$ - closed map , then the composition $g \cdot f : (X, \tau) \to (Z, \eta)$ is $sg^{\square}b$ - closed map.*

Proof. Let F be any closed set in (X, τ). Since f is closed map, $f(F)$ is closed set in (Y, σ). Since g is $sg^{\square}b$ - closed map, $g(f(F))$ is $sg^{\square}b$ - closed set in (Z, η). That is $g \cdot f(F) = g(f(F))$ is $sg^{\square}b$ closed. Hence $g \cdot f$ is $sg^{\square}b$ closed map. □

Remark 3.23. If $f : (X, \tau) \to (Y, \sigma)$ is $sg^{\square}b$ - closed map and $g : (Y, \sigma) \to (Z, \eta)$ is closed map, then the composition need not $sg^{\square}b$ - closed map .

Theorem 3.24. *A map $f : (X, \tau) \to (Y, \sigma)$ is $sg^{\square}b$ - closed if and only if for each subset S of (Y, σ) and each open set U containing $f^{-1}(S) \subset U$, there is a $sg^{\square}b$ - open set V of (Y, σ) such that $S \subset V$ and $f^{-1}(V) \subset U$.*

Proof. Suppose f is $sg^{\square}b$ - closed. Let $S \subset Y$ and U be an open set of (X, τ) such that $f^{-1}(S) \subset U$. Now $X - U$ is closed set in (X, τ). Since f is $sg6 * b$ - closed, $f(X - U)$ is $sg^{\square}b$ - closed set in (Y, σ). There fore $V = Y f(X - U)$ is an $sg^{\square}b$ - open set in (Y, σ). Now $f^{-1}(S) \subset U$ implies $S \subset V$ and $f^{-1}(V) = X - f^{-1}(f(X - U)) \subset X - (X - V) = U$. (ie) $f^{-1}(V) \subset U$.

Conversely,

Let F be a closed set of (X, τ). Then $f^{-1}(f(F^c)) \subset F^c$ and F^c is an open in (X, τ). By hypothesis, there exist a $sg^{\star}b$ - open set V in (Y, σ) such that $f(F^c) \subset V$ and $f^{-1}(V) \subset F^c \Rightarrow F \subset f^{-1}(V)^c$. Hence $V^c \subset f(F) \subset f(((f^{-1}(V))^c)^c \subset V^c \Rightarrow f(V) \subset V^c$. Since V^c is $sg^{\star}b$ - closed, $f(F)$ is $sg^{\star}b$ - closed. (ie) $f(F)$ is $sg^{\star}b$ - closed in Y. Therefore f is $sg^{\star}b$ - closed. $\square$

Theorem 3.25. *If $f : X_1 \times X_2 \to Y_1 \times Y_2$ is defined as $f(x_1, x_2) = (f_1(x_1), f_2(x_2))$, then $f : X_1 \times X_2 \to Y_1 \times Y_2$ is $sg^{\star}b$ closed map.*

Proof. Let $U_1 \times U_2 \subset X_1 \times X_2$ where $U_i \in sg^{\star}bcl(X_i)$, for $i = 1, 2$. Then $f(U_1 \times U_2) = f_1(U_1) \times f_2(U_2) \in sg^{\star}bcl(X_1 \times Y_2)$. Hence f is $sg^{\star}b$ - closed set. $\square$

Theorem 3.26. *Let $h : X \to X_1 \times X_2$ be $sg^{\star}b$ - closed map and Let $f_i : X \times X_i$ be define as $h(x) = (x_1, x_2)$ and $f_i(x) = x_i$, then $f_i : X \times X_i$ is $sg^{\star}b$ - closed map for $i = 1, 2$.*

Proof. Let $U_1 \times U_2 \in X_1 \times X_2$, then $f_1(U_1) = h_1(U_1 \times X_2) \in sg^{\star}bcl(X)$, there fore f_1 is $sg^{\star}b$ - closed. Similarly we have f_2 is $sg^{\star}b$ - closed. Thus f_i is $sg^{\star}b$ - closed map for $i = 1, 2$. $\square$

Theorem 3.27. *For any bijection map $f : (X, \tau) \to (Y, \sigma)$, the following statements are equivalent:*
(i) $f^{-1} : (Y, \sigma) \to (X, \tau)$ is $sg^{\star}b$ - continuous.
(ii) f is $sg^{\star}b$ - open map.
(iii) f is $sg^{\star}b$ - closed map.

Proof. (i)$\Rightarrow$(ii) Let U be an open set of (X, τ). By assumption, $(f^{-1})^{-1}(U) = f(U)$ is $sg^{\star}b$ - open in (Y, σ) and so f is $sg^{\star}b$ - open.

(ii)$\Rightarrow$(iii) Let F be a closed set of (X, τ). Then F^c is open set in (X, τ). By assumption $f(F^c)$ is $sg^{\star}b$ - open in (Y, σ). Therefore $f(F^c) = f(F)^c$ is $sg^{\star}b$ - open in (Y, σ). That is $f(F)$ is $sg^{\star}b$ - closed in (Y, σ). Hence f is $sg^{\star}b$ - closed.

(iii)$\Rightarrow$(i) Let F be a closed set of (X, τ). By assumption, $f(F)$ is $sg^{\star}b$ - closed in (Y, σ). But $f(F) = (f^{-1})^{-1}(F) \Rightarrow (f^{-1})$ is continuous. $\square$

4. On Semi Generalized sg^*b-Open Map

In this section, we introduce semi generalized star b - open map (briefly $sg^{\star}b$ - open) in topological spaces by using the notions of $sg^{\star}b$ - open sets and study some of their properties.

Definition 4.1. Let X and Y be two topological spaces. A map $f : (X, \tau) \to (Y, \delta)$ is called semi generalized star b - open (briefly, $sg^{\star}b$ - open) if the image of every open set in X is $sg^{\star}b$ - open in Y.

Theorem 4.2. *Every open map is $sg^{\star}b$ - open but not conversely.*

Proof. Let $f : (X, \tau) \to (Y, \delta)$ is open map and V be an open set in X then $f(V)$ is open in Y. Hence $sg^{\star}b$ - open in Y. Then f is $sg^{\star}b$ - open. □

The converse of above theorem need not be true as seen from the following example.

Example 4.3. Consider $X = Y = \{a, b, c\}$,$\tau = \{X, \phi, \{a\}, \{b\}, \{a, b\}\}$ and $\sigma = \{Y, \phi, \{a, b\}\}$. Let $f : (X, \tau) \to (Y, \sigma)$ be defined by $f(a) = c, f(b) = a, f(c) = b$. The map is $sg^{\star}b$ - open but not open as the image of and $\{a, c\}$ in X is $\{b, c\}$ is not open in Y.

Theorem 4.4. *A map $f : (X, \tau) \to (Y, \sigma)$ is $sg^{\star}b$ - closed set if and only if for each subset S of Y and for each open set U containing $f^{-1}(S) \subset U$ there is a $sg^{\star}b$ - open set V of Y such that $S \subset U$ and $f^{-1}(V) \subset U$.*

Proof. Suppose f is $sg^{\star}b$ - closed set. Let $S \subset Y$ and U be an open set of (X, τ) such that $f^{-1}(S) \subset U$. Now $X - U$ is closed set in (X, τ). Since f is $sg^{\star}b$ closed, $f(X - U)$ is $sg^{\star}b$ closed set in (Y, σ). Then $V = Y - f(X - U)$ is $sg^{\star}b$ open set in (Y, σ). There fore $f^{-1}(S) \subset U$ implies $S \subset V$ and $f^{-1}(V) = X - f^{-1}(f(X - U)) \subset X - (X - V) = U$. (ie) $f^{-1}(V) \subset U$.

Conversely,

Let F be a closed set of (X, τ). Then $f^{-1}(f(F^c)) \subset F^c$ and F^c is an open in (X, τ). By hypothesis, there exists a $sg^{\star}b$ open set V in (Y, σ) such that $f(F^c) \subset V$ and $f^{-1}(V) \subset F^c \Rightarrow F \subset (f^{-1}(V)^c$. Hence $V^c \subset f(F) \subset f(((f^{-1}(V))^c)^c) \subset V^c \Rightarrow f(V) \subset V^c$. Since V^c $sg^{\star}b$ - closed, $f(F)$ is $sg^{\star}b$ - closed. (ie) $f(F)$ is $sg^{\star}b$ - closed in (Y, σ) and there fore f is $sg^{\star}b$ - closed. □

Theorem 4.5. *For any bijection map $f : (X, \tau) \to (Y, \sigma)$, the following statements are equivalent.*
(i) $f^{-1} : (X, \tau) \to (Y, \sigma)$ is $sg^{\star}b$ - continuous.

(ii) f is $sg^{*}b$ open map.
(iii) f is $sg^{*}b$ - closed map.

Proof. (i)$\Rightarrow$ (ii) Let U be an open set of (X, τ). By assumption $(f^{-1})^{-1}(U) = f(U)$ is $sg^{*}b$ - open in (Y, σ). There fore f is $sg^{*}b$ - open map.

(ii)$\Rightarrow$ (iii) Let F be closed set of (X, τ), Then F^c is open set in (X, τ). By assumption, $f(F^c)$ is $sg^{*}b$ - open in (Y, σ). There fore $f(F)$ is $sg^{*}b$ - closed in (Y, σ).

Hence f is $sg^{*}b$- closed.

(iii)$\Rightarrow$ (i) Let F be a closed set of (X, τ), By assumption $f(F)$ is $sg^{*}b$ - closed in (Y, σ). But $f(F) = (f^{-1})^{-1}(F)$.

Hence $f^{-1} : (X, \tau) \rightarrow (Y, \sigma)$ is $sg^{*}b$ -continuous. □

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