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ON bg^μ-CLOSED MAPS AND bg^μ-HOMEOMORPHISMS IN SUPRA TOPOLOGICAL SPACES

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Abstract: The aim of this paper, is to introduce a new class of set namely bg^μ - closed maps and bg^μ - homeomorphisms in supra topological spaces and study some of their properties. Using these new types of maps, several properties have been obtained.

Keywords and Phrases: bg^μ - closed map; bg^μ - homeomorphism and $^*bg^\mu$ - homeomorphism.

2010 Mathematics Subject Classification: 54C05, 57S05.

1. Introduction

In 1983, Mashhour et al [7] introduced the concept of supra topological spaces and studied S- continuous maps and S^*- continuous maps. In 2010, Sayed et al [9] introduced and investigated several properties of supra b-open sets and supra b-continuity. In this paper, we introduce the concept of bg^μ-closed maps and study its basic properties. Also, we introduce the concept of bg^μ-homeomorphisms and investigate several properties for these classes of functions in supra topological spaces.

2. Preliminaries

Definition 2.1. *[7], [9] A subfamily of μ of X is said to be a supra topology on X, if*
(i) X, $\phi \in \mu$
(ii) if $A_i \in \mu$ for all $i \in J$ then $\cup A_i \in \mu$.

The pair (X,μ) is called supra topological space. The elements of μ are called supra open sets in (X,μ) and complement of a supra open set is called a supra closed set.

Definition 2.2. *[7], [9]*
(i) The supra closure of a set A is denoted by $cl^\mu(A)$ and is defined as
$cl^\mu(A) = \cap \{B: B$ *is a supra closed set and* $A \subseteq B\}$.
(ii) The supra interior of a set A is denoted by $int^\mu(A)$ and defined as
$int^\mu(A) = \cup \{B: B$ *is a supra open set and* $A \supseteq B\}$.

Definition 2.3. *[7] Let (X,τ) be a topological spaces and μ be a supra topology on (X,τ). We call μ a supra topology associated with τ if $\tau \subset \mu$.*

Definition 2.4. *[9] Let (X,μ) be a supra topological space. A set A is called a supra b-open set if $A \subseteq cl^\mu(int^\mu(A)) \cup int^\mu(cl^\mu(A))$. The complement of a supra b-open set is called a supra b-closed set.*

Definition 2.5. *[8] A subset A of a supra topological space (X,μ) is called g^μ-closed set if $cl^\mu(A) \subseteq \bigcup$, whenever $A \subseteq \bigcup$ and $\bigcup$ is supra open in (X,μ).*

The complement of g^μ-closed set is called g^μ-open set.

Definition 2.6. *A subset A of a supra topological space (X,μ) is called bg^μ-closed set if $cl^\mu(A) \subseteq \bigcup$, whenever $A \subseteq \bigcup$ and $\bigcup$ is b^μ-open in (X,μ).*

The complement of bg^μ-closed set is called bg^μ-open set.

Definition 2.7. *[5] A subset A of a supra topological space (X,μ) is called bT^μ-closed set if $bcl^\mu(A) \subseteq \bigcup$, whenever $A \subseteq \bigcup$ and U is T^μ-open in (X,μ). The complement of supra bT^μ-closed set is called bT^μ-open set.*

Definition 2.8. *[5] Let (X,τ) and (Y,σ) be two supra topological spaces. A function f:(X,τ) $\to$ (Y,σ) is called bT^μ-Continuous if $f^{-1}(V)$ is bT^μ-closed in (X,μ) for every supra closed set V of (Y,σ).*

Definition 2.9. *[3] A subset A of (X,μ) is called T^μ-closed set if $bcl^\mu(A) \subseteq \bigcup$, whenever $A \subseteq \bigcup$ and $\bigcup$ is gb^μ-open in (X,μ). The complement of T^μ- closed set is called T^μ-open set.*

Definition 2.10. *[5] Let (X,τ) and (Y,σ) be two supra topological spaces. A function f :(X,τ) $\rightarrow$ (Y,σ) is called bT^μ-irresolute if f^{-1}(V) is bT^μ-closed in (X,μ) for every bT^μ-closed set V of (Y,σ).*

Definition 2.11. *Let (X,τ) and (Y,σ) be two supra topological spaces. A function f:(X,τ) $\rightarrow$ (Y,σ) is called bg^μ-Continuous if f^{-1}(V) is bg^μ-closed in (X,μ) for every supra closed set V of (Y,σ).*

Definition 2.12. *Let (X,τ) and (Y,σ) be two supra topological spaces. A function f :(X,τ) $\rightarrow$ (Y,σ) is called bg^μ-irresolute if f^{-1}(V) is bg^μ-closed in (X,μ) for every bg^μ-closed set V of (Y,σ).*

Definition 2.13. *[8] Let f :(X,τ) $\rightarrow$ (Y,σ) where μ and λ are supra topological spaces associated with τ and σ, respectively. Then f is called supra M-closed if the image of every supra closed set of X is supra closed set in Y.*

Definition 2.14. *[6] A map f :(X,τ) $\rightarrow$ (Y,σ) is said to be bT^μ-closed map (bT^μ-open map) if the image f(A) is bT^μ-closed (bT^μ-open) in (Y,σ) for each supra closed (supra open) set A in (X,σ).*

Definition 2.15. *[6] A bijection f :(X,τ) $\rightarrow$ (Y,σ) is called bT^μ-homeomorphism if f is both bT^μ-continuous and bT^μ closed map.*

Definition 2.16. *[8] A map f :(X,τ) $\rightarrow$ (Y,σ) is said to be g^μ-closed map (g^μ-open map) if the image f(A) is g^μ-closed (g^μ-open) in (Y,σ) for each supra closed (supra open) set A in (X,σ).*

Definition 2.17. *[8] A bijection f :(X,τ) $\rightarrow$ (Y,σ) is called g^μ-homeomorphism if f is both g^μ-continuous and g^μ closed map.*

3. Basic Properties of bg^μ - Closed Maps

Definition 3.1. *A map f :(X,τ) $\rightarrow$ (Y,σ) is said to be bg^μ-closed map (bg^μ-open map) if the image f(A) is bg^μ-closed (bg^μ-open) in (Y,σ) for each supra closed (supra open) set A in (X,τ).*

Theorem 3.2. *Every supra M-closed map is bg^μ-closed map.*
Proof. Let f :(X,τ) $\rightarrow$ (Y,σ) be supra M-closed map. Let V be supra closed set in (X,τ), Since f is supra M-closed map then f(V) is supra closed set in (Y,σ). We know that every supra closed set is supra bg^μ-closed, then f(V) is supra bg^μ-closed in (Y,σ). Therefore f is supra bg^μ-closed map.

The converse of the above theorem need not be true. It is shown by the following example.

Example 3.3. *Let $X = Y = \{a, b, c\}$, $\tau = \{X, \phi, \{b\}\}$ and $\sigma = \{Y, \phi, \{a\}, \{b, c\},$*

$\{a,c\}\}$. The bg^{μ}-closed sets of (Y, σ) are $\{Y,\phi,\{a\},\{b\},\{c\},\{b,c\},\{a,c\}\}$. Let f:(X,$\tau$) $\rightarrow$ (Y,σ) be a function defined by f(a) = a, f(b) = b, f(c) = c. Let $V = \{a,c\}$ in supra closed set of (X,τ), f(V) = f$\{a,c\} = \{a,c\}$ is bg^{μ}-closed in (Y,σ) but not supra closed in (Y,σ).

Theorem 3.4. *Every bg^{μ}-closed map is bT^{μ}-closed map.*
Proof. Let f :(X,τ) $\rightarrow$ (Y,σ) be a bT^{μ}-closed map. Let V be supra closed set in (X,τ) Since f is supra bg^{μ}-closed map then f(V) is bT^{μ}-closed set in (Yσ). We know that every bg^{μ}-closed set is bT^{μ}-closed, then f(V) is bT^{μ}-closed in (Y,σ). Therefore f is bT^{μ}-closed map.

The converse of the above theorem need not be true. It is shown by the following example.

Example 3.5. *Let $X = Y = \{a,b,c\}$, $\tau = \{X,\phi,\{a,b\},\{c,d\},\{a,b,d\},\{b,c,d\}\}$ and $\sigma = \{X,\phi,\{a,c\},\{c,d\}\}$. The bT^{μ}-closed sets are $\{X,\phi,\{a\}, \{b\}, \{c\}, \{d\}, \{a,b\}, \{b,c\}, \{c,d\}, \{a,c\}, \{a,d\}, \{b,d\}, \{a,c,d\}, \{a,b,c\}, \{a,b,d\}, \{b,c,d\}\}$ and the bg^{μ}-closed sets are $\{X,\phi,\{a\},\{c\},\{a,b\},\{c,d\}\}$. Let f:(X,$\tau$) $\rightarrow$ (Y,σ) be a function defined by*
f(a) = a, f(b) = b, f(c) = c. Let $V = \{a,c\}$ in supra closed set of (X,τ), f(V) = f$\{a,c\} = \{a,c\}$ is bT^{μ}-closed but not bg^{μ}-closed.

Theorem 3.6. *Every bg^{μ}-closed map is g^{μ}-closed map.*
Proof. Let f :(X,τ) $\rightarrow$ (Y,σ) be A g^{μ}-closed map. Let V be supra closed set in (X,τ), Since f is supra bg^{μ}-closed map then f(V) is g^{μ}-closed set in (Y,σ). We know that every bg^{μ}-closed set is g^{μ}-closed, then f(V) is g^{μ}-closed in (Y,σ). Therefore f is g^{μ}-closed map.

The converse of the above theorem need not be true. It is shown by the following example.

Example 3.7. *Let $X = Y = \{a,b,c\}$, $\tau = \{X,\phi,\{a,c\}\}$ and $\sigma = \{Y,\phi,\{c\}, \{a,b\}, \{b,c\}\}$. The g^{μ}-closed sets of (Y,σ) are $\{Y,\phi,\{a\},\{b\},\{c\},\{a,b\},\{a,c\}\}$ and bg^{μ}-closed sets of (Y,σ) are $\{Y,\phi,\{a\},\{c\},\{a,b\}\}$. Let f:(X,$\tau$) $\rightarrow$ (Y,σ) be a function defined by*
f(a) = a, f(b) = b, f(c) = c. Let $V = \{a,c\}$ in supra closed set of (X,τ),
f(V) = f$\{a,c\} = \{a,c\}$ is g^{μ}-closed but not bg^{μ}-closed.

Theorem 3.8. *A mapping f :(X,τ) $\rightarrow$ (Y,σ) is bg^{μ}-closed if and only if $bg - cl^{\mu} f(A) \subseteq f(cl^{\mu}(A))$ for every subset A of (X,τ).*
Proof. Suppose that f is bg^{μ}-closed and $A \subseteq X$. Then $f(cl^{\mu}(A))$ is bg^{μ}-closed in (Y,σ). We have $A \subseteq (cl^{\mu}(A))$. Thus $f(A) \subseteq f(cl^{\mu}(A))$. Then
$bg - cl^{\mu} f(A) \subseteq bg - (cl^{\mu} f(cl^{\mu}(A))) = f(cl^{\mu}(A))$.

Conversely, let A be any closed set in(X,τ). Then $A = cl^\mu(A)$. Thus $f(A) = f(cl^\mu(A))$. But $bg - cl^\mu f(A) \subseteq f(cl^\mu(A)) = f(A)$. Also $f(A) \subseteq bg - cl^\mu(f(A))$. Thus f(A) is bg^μ-closed and hence f is bg^μ-closed.

Theorem 3.9. *A mapping f :(X,τ) $\rightarrow$ (Y,σ) is bg^μ-open if and only if $bg - int^\mu f(A) \subseteq f(int^\mu(A))$ for every subset A of (X,τ).*

Proof. Suppose that f is bg^μ-open and $A \subseteq X$. Then $f(int^\mu(A))$ is bg^μ-open in (Y,σ). We have $A \subseteq (int^\mu(A))$. Thus $f(A) \subseteq f(int^\mu(A))$. Then $bg - int^\mu f(A) \subseteq bg - (int^\mu f(int^\mu(A))) = f(int^\mu(A))$.

Conversely, let A be any open set in(X,τ). Then $A = int^\mu(A)$. Thus $f(A) = f(int^\mu(A))$. But $bg - int^\mu f(A) \subseteq f(int^\mu(A)) = f(A)$. Also $f(A) \subseteq bg - int^\mu(f(A))$. Thus f(A) is bg^μ-open and hence f is bg^μ-open.

Remark 3.10. *The composition of two bg^μ-closed maps need not be bg^μ-closed map. It is show by the following example*

Example 3.11. *Let $X = Y = Z = \{a, b, c\}$. Let $\tau = \{X, \phi, \{b\}, \{a, b\}, \{b, c\}, \{a, c\}\}$, $\sigma = \{Y, \phi, \{a\}, \{b, c\}, \{a, c\}\}$ and $\eta = \{Z, \phi, \{a\}, \{b\}, \{a, b\}, \{b, c\}, \{a, c\}\}$. The bg^μ-closed sets of (Y,σ) are $\{Y, \phi, \{a\}, \{b\}, \{c\}, \{b, c\}, \{a, c\}\}$ and bg^μ-closed sets of (Z,η) are $\{Z, \phi, \{a\}, \{b\}, \{c\}, \{b, c\}\}$. f :(X,τ) $\rightarrow$ (Y,σ) and g :(Y,τ) $\rightarrow$ (Z,ζ) be the identity function. Then $(gof)\{a, c\} = g(f\{a, c\}) = g(\{a, c\}) = \{a, c\}$ is not supra bg^μ-closed map in (Z,ζ).*

Theorem 3.12. *If f :X $\rightarrow$ Y is a supra closed map and g :Y $\rightarrow$ Z is bg^μ-closed map then the composition gof :X $\rightarrow$ Z is supra bg^μ-closed map.*

Proof. Let f :X $\rightarrow$ Y is a closed map and g :Y $\rightarrow$ Z is a supra bg^μ-closed map. Let V be any supra closed set in (X,τ). Since f :X $\rightarrow$ Y is closed map, $f(V)$ is closed in Y and since g:Y $\rightarrow$ Z is supra bg^μ-closed map, $g(f(V))$ is supra bg^μ-closed map in Z. This implies gof :X $\rightarrow$ Z is supra bg^μ-closed map.

Remark 3.13. *If f :X $\rightarrow$ Y is a supra bg^μ-closed map and g :Y $\rightarrow$ Z is supra M closed map then the composition need not be supra bg^μ-closed map. It can be seen by the following example.*

Example 3.14. *Let $X = Y = Z = \{a, b, c\}$. Let $\tau = \{X, \phi, \{b\}, \{a, b\}, \{b, c\}, \{a, c\}\}$, $\sigma = \{Y, \phi, \{a\}, \{b, c\}, \{a, c\}\}$ and $\zeta = \{Z, \phi, \{a\}, \{b\}, \{a, b\}, \{b, c\}, \{a, c\}\}$. The bg^μ-closed sets of (Y,σ) are $\{Y, \phi, \{a\}, \{b\}, \{c\}, \{b, c\}, \{a, c\}\}$ and bg^μ-closed sets of (Z,ζ) are $\{Z, \phi, \{a\}, \{b\}, \{c\}, \{b, c\}\}$. $f : (X, \tau) \rightarrow (Y, \sigma)$ be the function defined by f(a) = a, f(b) = b,f(c) = c and $f : (Y, \tau) \rightarrow (Z, \zeta)$ be the function defined by $g(a) = a$, $g(b) = b$, $g(c) = c$. Here f is supra bg^μ-closed map and g is supra M closed map, but its composition is not supra bg^μ-closed map, since gof$(\{a, c\}) = \{a, c\}$ is not supra bg^μ-closed map in (Z,ζ).*

Theorem 3.15. *For any bijection $f : (X, \tau) \to (Y, \sigma)$ the following are statement are equivalent*
(i) $f^{-1} : (Y, \sigma) \to (X, \tau)$ is bg^μ-continuous.
(ii) f is bg^μ-open map.
(iii) f is bg^μ-closed map.
Proof. $(i) \Rightarrow (ii)$ Let U be an supra open set of (X,τ). By assumption $(f^{-1})^{-1} =$ f(U) is bg^μ-open in (Y,σ) and so f is bg^μ-open.
$(ii) \Rightarrow (iii)$ Let F be a supra closed set of (X,τ). Then F^c is supra open in (X,τ). By assumption, f(F^c) is bg^μ-open in (Y,σ) and therefore f(F) is bg^μ-closed in (Y,σ). Hence f is bg^μ-closed.
$(iii) \Rightarrow (i)$ Let F be a supra closed set of (X,τ). By assumption, f(F) is bg^μ - closed in (Y,σ). But f(F)=$(f^{-1})^{-1}(F)$ and therefore f^{-1} is bg^μ-continuous on (Y,σ).

4. bg^μ - Homeomorphism

Definition 4.1. *A bijection f :(X,τ) $\to$ (Y,σ) is called bg^μ-homeomorphism if f is both bg^μ-continuous and bg^μ closed map.*

Example 4.2. *Let $X = Y = \{a, b, c\}$, $\tau = \{X, \phi, \{b\}, \{a, b\}, \{b, c\}, \{a, c\}\}$ and $\sigma = \{Y, \phi, \{a\}, \{b, c\}, \{a, c\}\}$. The bg^μ-closed sets of (X,τ) are $\{X, \phi, \{a\}, \{b\}, \{c\}, \{a, b\}, \{b, c\}, \{a, c\}\}$ and bg^μ-closed sets of (Y,σ) are $\{Y, \phi, \{a\}, \{b\}, \{c\}, \{b, c\}, \{a, c\}\}$. Define f :(X,$\tau$) $\to$ (Y,σ) be the identity maps. Then f is bg^μ-homeomorphism.*

Theorem 4.3. *Let f :(X,τ) $\to$ (Y,σ) be a bijective, bg^μ-continuous map. Then the following are equivalent*
(i) f is bg^μ-open map.
(ii) f is bg^μ-homeomorphism.
(iii) f is bg^μ-closed map.
Proof. $(i) \Rightarrow (ii)$ Given f :(X,τ) $\to$ (Y,σ) be a bijective bg^μ-continuous and bg^μ-open. Then by definition, f is an bg^μ-homeomorphism.
$(ii) \Rightarrow (iii)$ Given f is bg^μ-open and bijective. By theorem 3.15(ii), f is a bg^μ-closed map.
$(iii) \Rightarrow (i)$ Given f is bg^μ-closed and bijective. By theorem 3.15(iii), f is a bg^μ-open map.

Remark 4.4. *The following example shows that the composition of two bg^μ - homeomorphism is need not be a bg^μ - homeomorphism.*

Example 4.5. *Let $X = Y = Z = \{a, b, c\}$, $\tau = \{X, \phi, \{b\}, \{a, b\}, \{b, c\}, \{a, c\}\}$, $\sigma = \{Y, \phi, \{a\}, \{b, c\}, \{a, c\}\}$ and $\eta = \{Z, \phi, \{a\}, \{b\}, \{a, b\}, \{b, c\}, \{a, c\}\}$. The bg^μ-closed sets of (X,τ) are $\{X, \phi, \{a\}, \{b\}, \{c\}, \{a, b\}\}$, bg^μ-closed sets of (Y,σ)*

are $\{Y, \phi, \{a\},$
$\{b\}, \{c\}, \{b,c\}, \{a,c\}\}$ *and* bg^{μ}*-closed sets of* (Z,η) *are* $\{Z, \phi, \{a\}, \{b\}, \{c\}, \{b,c\}\}$. *Then both f and g are* bg^{μ}*-homeomorphism, but their composition gof:* $f : (X,\tau) \to (Z,\eta)$ *is not* bg^{μ}*-homeomorphism, because for the supra closed set* $\{a,c\}$ *of* (X,τ) $(gof)\{a,c\} = g(f\{a,c\}) = g(\{a,c\}) = \{a,c\}$*, which is not* bg^{μ}*-closed in* (Z,η). *Therefore gof is not* bg^{μ}*-closed and so gof is not* bg^{μ}*-homeomorphism.*

Definition 4.6. *A bijection* $f : (X,\tau) \to (Y,\sigma)$ *is called* $^{*}bg^{\mu}$*-homeomorphism if both f and* f^{-1} *are* bg^{μ}*-irresolute.*

Example 4.7 *Let* $X = Y = \{a,b,c\}$, $\tau = \{X, \phi, \{b\}, \{a,b\}, \{b,c\}, \{a,c\}\}$ *and* $\sigma = \{Y, \phi, \{a\}, \{b,c\}, \{a,c\}\}$. *The* bg^{μ}*-closed sets of* (X,τ) *are* $\{X, \phi, \{a\}, \{b\}, \{c\}, \{a,b\}, \{b,c\}, \{a,c\}\}$ *and* bg^{μ}*-closed sets of* (Y,σ) *are* $\{Y, \phi, \{a\}, \{b\}, \{c\}, \{b,c\}, \{a,c\}\}$. *Define* $f : (X,\tau) \to (Y,\sigma)$ *be the identity by f(a) = a, f(b) = b, f(c) = c. Then f is* $^{*}bg^{\mu}$*-homeomorphism.*

Theorem 4.8. *Every* $^{*}bg^{\mu}$*-homeomorphism is* bg^{μ}*-irresolute.*
Proof. Let f be a $^{*}bg^{\mu}$-homeomorphism. By the definition of $^{*}bg^{\mu}$-homeomorphism, f is bg^{μ}-irresolute.

Remark 4.9. *Every* bg^{μ}*-irresolute map need not be a* $^{*}bg^{\mu}$*-homeomorphism.*

Example 4.10. *Let* $X = Y = \{a,b,c\}$, $\tau = \{X, \phi, \{b\}, \{a,b\}, \{b,c\}, \{a,c\}\}$ *and* $\sigma = \{Y, \phi, \{a\}, \{b,c\}, \{a,c\}\}$. *The* bg^{μ}*-closed sets of* (X,τ) *are* $\{X, \phi, \{a\}, \{b\}, \{c\}, \{a,b\}, \{b,c\}, \{a,c\}\}$ *and* bg^{μ}*-closed sets of* (Y,σ) *are* $\{Y, \phi, \{a\}, \{b\}, \{c\}, \{b,c\}, \{a,c\}\}$. *Define* $f : (X,\tau) \to (Y,\sigma)$ *be the identity by f(a) = a, f(b) = c, f(c) = b. Then f is* bg^{μ}*-irresolute, but not* $^{*}bg^{\mu}$*-homeomorphism. Since* $f(\{a,c\}) = \{a,b\}$ *which is not in* bg^{μ}*-closed in* (Y,σ).

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