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GENERALIZED PRE CLOSED SEPARATION AXIOMS IN TOPOLOGICAL SPACES

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ABSTRACT

The aim of this paper is to introduce and study two new classes of spaces,namely Generalized pre closed-normal and Generalized pre closed-regular spaces and obtained their properties by utilizing Generalized pre closed-closed sets.

Keywords: *Generalized pre closed set, Generalized pre closed-continuous function,Generalized pre closed-Separation axioms,Generalized pre open set.*

Mathematics subject classification (2010): *54A05.*

1. INTRODUCTION

H. Maki, J.Umehara and T.Noiri,Introduced gp-closed sets and , Benchalli et al and Shik John studied the concept of g* - pre-regular, g*-pre normal and w- normal, w-regular spaces in topological spaces. Recently, Benchalli et al introduced and studied the properties of regular weakly closed sets and regular weakly continuous functions.

2. PRELIMINARIES

Throughout this paper space (X, τ) and (Y, σ) (or simply X and Y) always denote topological space on which no separation axioms are assumed unless explicitly stated. For a subset A of a space X, Cl(A), Int(A), A^c , and α-Cl(A), denote the Closure of A, Interior of A and Compliment of A and α-closure of A in X respectively.

Definition 2.1: A subset A of a topological space (X, τ) is called

(i) W-closed set if cl(A) ⊆ U whenever A⊆ U and U is semi-open in X.

(ii) Generalized closed set(briefly g-closed) [7] if cl(A)⊆U whenever A ⊆ U and U is open in X.

Definition 2.2: A topological space X is said to be a

(1) α - regular ,if for each α - closed set F of X and each point x ∉ F, there exists disjoint α - open sets U and V such that F ⊆ V and x ϵ U.
(2) w-regular, if for each closed set F of X and each point x ∉ F, there exists disjoint w-open sets U and V such that F⊆U and xϵ V.
(3) g-regular, if for each g-closed set F of X and each point x ∉F,there exists disjoint open sets U and V such that F⊆U and x ϵ V .

Definition 2.3. A topological space X is said to be a

(1) α-normal, if for any pair of disjoint α − closed sets A and B, there exists disjoint α -open sets U and V such that A⊆U and B⊆V.
(2) w-normal, if for any pair of disjoint w -closed sets A and B, there exists disjoint open sets U and V such that A ⊆ U and B⊆V.

Definition 2.4: A topological space X is called $T_{\text{Generalized pre closed}}$ - space if every Generalized pre closed-closed set in it is closed set.

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Definition 2.5: A map f: (X, τ) ⟶ (Y, τ) is said to be

(i) Generalized pre closed-continuous map if $f^{-1}(V)$is a Generalized pre closed set of (X, τ) for every closed set V of (Y, τ).

(ii) Generalized pre closed-irresolute map if $f^{-1}(V)$is a Generalized pre closed set of (X, τ) for every Generalized pre closed set V of (Y, τ).

3. GENERALIZED PRE CLOSED -REGULAR SPACES

In this section, we introduce a new class of spaces called Generalized pre closed-regular spaces using Generalized pre closed sets and obtain some of their characterizations.

Definition 3.1: A topological space X is said to be Generalized pre closed-regular if for each Generalized pre closed set F and a point x ∉ F, there exist disjoint open sets G and H such that F⊆G and x ϵ H.

We have the following interrelationship between Generalized pre closed-regularity and regularity.

Theorem 3.2: Every Generalized pre closed-regular space is regular.

Proof: Let X be a Generalized pre closed-regular space. Let F be any closed set in X and a point x∉X such that x∉F. Since, F is Generalized pre closed and x ∉ F. Since X is a Generalized pre closed-regular space, there exists a pair of disjoint open sets G and H such that F ⊆ G and x ϵ H. Hence X is a regular space.

Remark 3.3: If X is a regular space and $T_{\text{Generalized pre closed}}$ space, then X is Generalized pre closed regular We have the following characterization.

Theorem 3.4; The following statements are equivalent for a topological space X

(i) X is a Generalized pre closed regular space

(ii) For each x ϵ X and each Generalized pre open neighbourhood U of x there exists an open neighbourhood N of x such that cl(N)⊆U.

Proof: (i) implies (ii): Suppose X is a Generalized pre closed regular space. Let U be any Generalized pre open neighbourhood of x. Then there exists Generalized pre open set G such that x ϵ G ⊆U. Now X –G is Generalized pre closed set and x ∉ X - G. Since X is Generalized pre closed regular, there exist open sets M and N such that X-G⊆M, x ϵ N and M ∩ N = φ and so N ⊆X-M. Now cl(N) ⊆cl(X -M) = X-M and X -M ⊆ M. This implies X-M⊆ U. Therefore cl(N)⊆U.
(ii) implies (i): Let F be any Generalized pre closed set in X and x ϵ X -F and X - F is a Generalized pre open and so X - F is a Generalized pre closed-neighbourhood of x. By hypothesis, there exists an open neighbourhood N of x such that x ϵ N and cl(N)⊆X - F. This implies F⊆X - cl(N) is an open set containing F and N ∩ f(X - cl(N)= φ . Hence X is Generalized pre closed- regular space.

We have another characterization of Generalized pre closed-regularity in the following.

Theorem 3.5: A topological space X is Generalized pre closed-regular if and only if for each Generalized pre closed set F of X and each x ϵ X - F there exist open sets G and H of X such that x ϵ G, F⊆H and cl(G) ∩ cl(H) = ∅.

Proof: Suppose X is Generalized pre closed-regular space. Let F be a Generalized pre closed-set in X with x ∉ F.Then there exists open sets M and H of X such that x ϵ M, F ⊆H and M∩H =∅. This implies M∩cl(H) = ∅.As X is Generalized pre closed-regular, there exist open sets U and V such that x ϵ U, cl(H)⊆V and U∩V = ∅. so cl(U)∩V = ∅.Let G = M ∩ U, then G and H are open sets of X such that xϵG, F ⊆ H and cl(H) ∩ cl(H) =∅ .

Conversely, if for each Generalized pre closed set F of X and each x ϵ X -F there exists open sets G and H such that x ϵ G, F⊆ H and cl(H) ∩cl(H) = ∅ .This implies x ϵ G,F⊆H and G∩H = ∅. Hence X is Generalized pre closed- regular.

Now we prove that Generalized pre closed- regularity is a heriditary property.

Theorem 3.6: Every subspace of a Generalized pre closed-regular space is Generalized pre closed-regular.

Proof: Let X be a Generalized pre closed- regular space. Let Y be a subspace of X. Let x ϵ Y and F be a Generalized pre closed set in Y such that x∉F. Then there is a closed set and so Generalized pre closed set A of X with F = Y ∩ A and x ∉A. Therefore we have x ϵ X, A is Generalized pre closed in X such that x∉A. Since X is Generalized pre closed regular, there exist open sets G and H such that xϵG, A⊆H and G∩H = φ. Note that Y ∩ G and Y ∩ H are open sets in Y .Also x ϵ G and x ϵ Y, which implies x ϵ Y ∩G and A ⊆ H implies Y∩ G ⊆Y ∩ H,F⊆Y ∩ H. Also (Y ∩ G) ∩ (Y∩H) = φ. Hence Y is Generalized pre closed-regular space.

We have yet another characterization of Generalized pre closed -regularity in the following.

Theorem 3.7: The following statements about a topological space X are equivalent:
(i) X is Generalized pre closed -regular
(ii) For each x ϵ X and each Generalized pre open set U in X such that x ϵ U there exists an open set V in X such that x ϵ V⊆cl(V)⊆U.
(iii) For each point x ϵX and for each Generalized pre closed set A with x ∉ A, there exists an open set V containing x such that cl(V)∩A = φ.

Proof: (i)implies (ii): Follows from Theorem 3.5.

(ii)implies (iii): Suppose (ii) holds. Let x ϵ X and A be an Generalized pre closed set of X such that x ∉ A.Then X - A is a Generalized pre open set with x ϵ X -A. By hypothesis, there exists an open set V such that x ϵ V ⊆ cl(V)⊆ X - A. That is x ϵ V , V⊆ cl(A) and cl(A) ⊆ X - A. So x ϵ V and cl(V)∩A = φ.

(iii)implies(i): Let x ϵ X and U be an Generalized pre-open set in X such that x ϵ U. Then X - U is an Generalized pre closed set and x∉ X - U. Then by hypothesis, there exists an open set V containing x such that cl(A)∩(X -U) = Á. Therefore x ϵ V , cl(V)⊆U so x ϵ V⊆ cl(V)⊆ U.

The invariance of Generalized pre closed-regularity is given in the following.

Theorem 3.8: Let f : X $\rightarrow$ Y be a bijective, Generalized pre closed-irresolute and open map from a Generalized pre closed- regular space X into a topological space Y , then Y is Generalized pre closed-regular.

Proof: Let yϵY and F be a Generalized pre closed set in Y with y ∉ F. Since F is Generalized pre closed- irresolute, $f^{-1}(F)$ is Generalized pre closed set in X. Let f(x) = y so that x = f^{-1} (y) and x ∉ f^{-1}(F). Again X is Generalized pre closed regular space, there exist open sets U and V such that x ϵ U and f^{-1}(F) ⊆G, U ∩ V = φ. Since f is open and bijective, we have y ϵ f(U),F ⊆ f(V) and f(U) ∩ f(V) = f(U∩V) = f(φ) = φ . Hence Y is Generalized pre closed-regular space.

Theorem 3.9: Let f : X $\rightarrow$ Y be a bijective, Generalized pre closed and open map from a topological space X into a Generalized pre closed-regular space Y . If X is $T_{\text{Generalized pre closed}}$ space, then X is Generalized pre closed-regular.

Proof: Let x ϵ X and F be an Generalized pre closed set in X with x ∉ F. Since X is $T_{\text{Generalized pre closed}}$ space,F is closed in X. Then f(F) is Generalized pre closed set with f(x) ∉ f(F) in Y, since f is Generalized pre closed. As Y is Generalized pre closed-regular, there exist open sets U and V such that x ϵ U and f(x) ϵ U and f(F) ⊆V. Therefore x ϵ f^{-1}(U) and F ⊆ f^{-1}(V). Hence X is Generalized pre closed-regular space.

heorem 3.10: If f : X $\rightarrow$Y is w-irresolute, continuous injection and Y is Generalized pre closed-regular space,then X is Generalized pre closed- regular.

Proof: Let F be any closed set in X with x∉ F. Since f is w-irresolute, f is Generalized pre closed- set in Y and f(x) ϵ f(F). Since Y is Generalized pre closed- regular,there exists open sets U and V such that f(x) ϵ U and f(F) ⊆ V . Thus x ϵ f^{-1}(U),F ⊆ f^{-1}(V) and f^{-1} (U) ∩ f^{-1}(V) = φ. Hence X is Generalized pre closed- regular space.

4. GENERALIZED PRE CLOSED-NORMAL SPACES

In this section, we introduce the concept of Generalized pre closed normal spaces and study some of their characterizations.

Definition 4.1: A topological space X is said to be Generalized pre closed-normal if for each pair of disjoint Generalized pre closed-sets A and B in X, there exists a pair of disjoint open sets U and V in X such that A ⊆ U and B ⊆V

We have the following interrelationship.

Theorem 4.2: Every Generalized pre closed-normal space is normal.

Proof: Let X be a Generalized pre closed-normal space. Let A and B be a pair of disjoint closed sets in X. Since, A and B are Generalized pre closed sets in X. Since X is Generalized pre closed-normal, there exists a pair of disjoint open sets G and H in X such that A ⊆ G and B ⊆ H. Hence X is normal.

Remark 4.3: The converse need not be true in general as seen from the following example.

Example 4.4: Let X = Y ={a,b,c,d},τ ={X, ∅,{a},{c},{a,c},{b,c,d}} Then the space X is normal but not Generalized pre closed - normal, since the pair of disjoint Generalized pre closed sets namely, A = {a,d} and B = {b,c} for which there do not exists disjoint open sets G and H such that A ⊆ G and B⊆ H.

Remark 4.5: If X is normal and $T_{\text{Generalized pre closed}}$-space, then X is Generalized pre closed-normal.

Hereditary property of Generalized pre closed- normality is given in the following.

Theorem 4.6: A Generalized pre closed subspace of a Generalized pre closed - normal space is Generalized pre closed -normal. We have the following characterization.

Theorem 4.7: The following statements for a topological space X are equivalent:

(i) X is Generalized pre closed- normal
(ii) For each Generalized pre closed set A and each Generalized pre open set U such that A⊆U, there exists an open set V such that A⊆V⊆cl(V)⊆U
(iii) For any Generalized pre closed sets A, B, there exists an open set V such that A⊆V and cl(V)∩B = φ.
(iv) For each pair A, B of disjoint Generalized pre closed sets there exist open sets U and V such that A ⊆ U,B ⊆V and cl(U) ∩ cl(V) = φ.

Proof: (i) implies (ii): Let A be a Generalized pre closed set and U be a Generalized pre open set such that A⊆ U.Then A and X - U are disjoint Generalized pre closed sets in X. Since X is Generalized pre closed-normal , there exists a pair of disjoint open sets V and W in X such that A ⊆ V and X -U ⊆W. Now X -W ⊆ X - (X -U), so X -W⊆ U also V∩ W = φ. implies V ⊆ X -W, so cl(V) ⊆ cl(X -W) which implies cl(V)⊆X -W. Therefore cl(V) ⊆ X -W⊆ U. So cl(V) ⊆ U. Hence A ⊆ V ⊆ cl(V) ⊆ U.

(ii) implies (iii): Let A and B be a pair of disjoint Generalized pre closed sets in X. Now A∩ B = φ,so A⊆X -B, where A is Generalized pre closed and X - B is Generalized pre closed-open . Then by (ii) there exists an open set V such that A⊆V⊆cl(V)⊆ X - B. Now cl(V) ⊆ X - B implies cl(V) ∩ B = φ . Thus A⊆ V and cl(V) ∩ B = φ.

(iii) implies (iv): Let A and B be a pair of disjoint Generalized pre closed sets in X.Then from (iii) there exists an open set U such that A⊆U and cl(U) ∩ B = φ. Since cl(V) is closed, so Generalized pre closed set.Therefore cl(V) and B are disjoint Generalized pre closed sets in X. By hypothesis, there exists an open set V, such that B⊆V and cl(U) ∩cl(V) = φ.

(iv) implies (i): Let A and B be a pair of disjoint Generalized pre closed sets in X.Then from (iv) there exist an open sets U and V in X such that A⊆U, B⊆V and cl(U) ∩ cl(V) = φ. So A ⊆ U , B⊆V and U∩V = φ. Hence X Generalized pre closed-normal.

Theorem 4.8: Let X be a topological space. Then X is Generalized pre closed-normal if and only if for any pair A, B of disjoint Generalized pre closed sets there exist open sets U and V of X such that A⊆U,B⊆V and cl(U) ∩cl(V) = φ.

Theorem 4.9: Let X be a topological space. Then the following are equivalent:

(i) X is normal
(ii) For any disjoint closed sets A and B, there exist disjoint Generalized pre closed - open sets U and V such that A⊆U,B⊆V .
(iii) For any closed set A and any open set V such that A⊆ V, there exists an Generalized pre open set U of X such that A⊆U⊆ αcl(U)⊆V .

Proof: (i) implies (ii): Suppose X is normal. Since every open set is Generalized pre open

(ii) implies (iii): Suppose (ii) holds. Let A be a closed set and V be an open set containing A. Then A and X - V are disjoint closed sets. By (ii), there exist disjoint Generalized pre open sets U and W such that A⊆U and X - V ⊆ W, since X -V is closed, so Generalized pre closed. Since, we have
X -V⊆ α-int(W) and U ∩ α-int(W) = φ.and so we have α-cl(U) ∩ α-int(W) = φ. Hence A ⊆ U ⊆ α-cl(U) ⊆ X – α-int(W)⊆V . Thus A ⊆ U ⊆ α-cl(U) ⊆ V .

(iii) implies (i): Let A and B be a pair of disjoint closed sets of X.Then A ⊆ X - B and X -B is open. There exists a Generalized pre open set G of X such that A ⊆ G ⊆ α-cl(G) ⊆ X-B. Since A is closed, it is w- closed, we have A ⊆ α -int(G). Take U = int(cl(int(α-int(G))))
and V = int(cl(int(X –α-cl(G)))). Then U and V are disjoint open sets of X such that A ⊆ U and B ⊆ V . Hence X is normal.

We have the following characterization of Generalized pre closed - normality and Generalized pre closed- normality.

Theorem 4.10: Let X be a topological space. Then the following are equivalent:
(i) X is α-normal.
(ii) For any disjoint closed sets A and B, there exist disjoint Generalized pre open sets U and V such that A⊆ U,B⊆V and U∩ V = φ.

Proof: (i) implies (ii): Suppose X is α- normal. Let A and B be a pair of disjoint closed sets of X. Since X is α -normal,there exist disjoint $\alpha -$ open sets U and V such that A⊆U and B⊆V and U ∩ V = φ.

(ii) implies (i):Let A and B be a pair of disjoint closed sets of X.Then by hypothesis there exist disjoint Generalized pre open sets U and V such that A⊆U and B ⊆ V and U ∩V = φ .Since , A⊆ α-intU and B ⊆ $\alpha -$ int(V)and α –int U∩ α -intV = φ. Hence X is α -normal.

Theorem 4.11: Let X be a α- normal, then the following hold good:
(i) For each closed set A and every Generalized pre open set B such that A⊆B ther exists a α open set U such that A⊆U⊆ α-cl(U)⊆ B.
(ii) For every Generalized pre closed set A and every open set B containing A, there exist a α-open set U such that A⊆U⊆ α-cl(U)⊆B.

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