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Steel Product Development of Hot Rolled Coil Specification JIS G3106 SM520B Application in Steel Box Girder Elevated Toll Road MBZ, Jakarta-Cikampek

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SYNOPSIS

Indonesian Government want to solve the traffic jam Problem especially in the east Jakarta. To separate short & long distance traveler is build new elevated toll Road on the top of existing toll road is the best option. The steel has been chosen for girder box due to faster construction and longer span so it can reduce the pillars of elevated Road, 240.000 MT steel is needed to complete the project which spent around 16,23 billion Rupiah (1,1 Milliar USD). The elevated Toll Road named MBZ has a length of 36.4 kilometers From Jakarta to Cikampek Which construction has been in progress since early 2017 and was inaugurated by President Joko Widodo on December 12, 2019. According statistical data, the traffic density is around 200.000 Vehicle/day. This route is the lifeblood of the Indonesian economy and is located in a rapidly developing industrial and residential area east of Jakarta.

Steel Producer (Krakatau Steel) has to develop High Strength steel application in construction to meet the requirement from Constructor with specification JIS G3106 SM520B, this specification use for Bridges, ships, rolling stocks, petroleum storage tank, containers and other construction that have superior weldability

This Research focused on the development of high strength steel for Box Girder by addition Niobium and controlled rolling process to get the optimum mechanical properties. the result shown that material has excellent Yield Strength, Tensile Strength, Elongation also Impact Properties and comply to Standard JIS G3106 SM520B.

Keywords: Traffic Jam, steel girder box, superior weldability, high strength steel, Mechanical Properties

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I. INTRODUCTION

In the national five year plan (RPJMN 2015–2019), the Jokowi administration has pledged to build: 5,000 km of railways; 2,600 km of roads; 1,000 km of toll roads; forty-nine dams; twenty-four seaports; and power plants with a combined capacity of 35,000 megawatts (Bappenas 2014). Therefore, the big infrastructure plan set by the SBY government remains quite relevant. The difference between the Jokowi administration and its predecessor is the implementation of the plan. According to RPJMN 2015–2019, there are four key sectors will invest a significant amount of resources (Bappenas 2014)^[3] :

- Maritim Sector
- Food self–Sufficiency
- **Investment on Road & Railways**
- Increase energy Supply

According to IISIA (2020) the biggest steel consumption is a building & infrastructure sector. More than 50% use for construction, As a state owned company in Indonesia, PT KS must support government program , especially for Investment on Road & Railways by providing high quality steel material application for elevated toll road MBZ. Steel Standard JIS G3106 SM520B that is High Strength Low Alloy Steel is required to respond to the project. The addition of Niobium microalloy and appropriate rolling parameters has been made to attain the minimum mechanical properties T_s 520 Mpa.

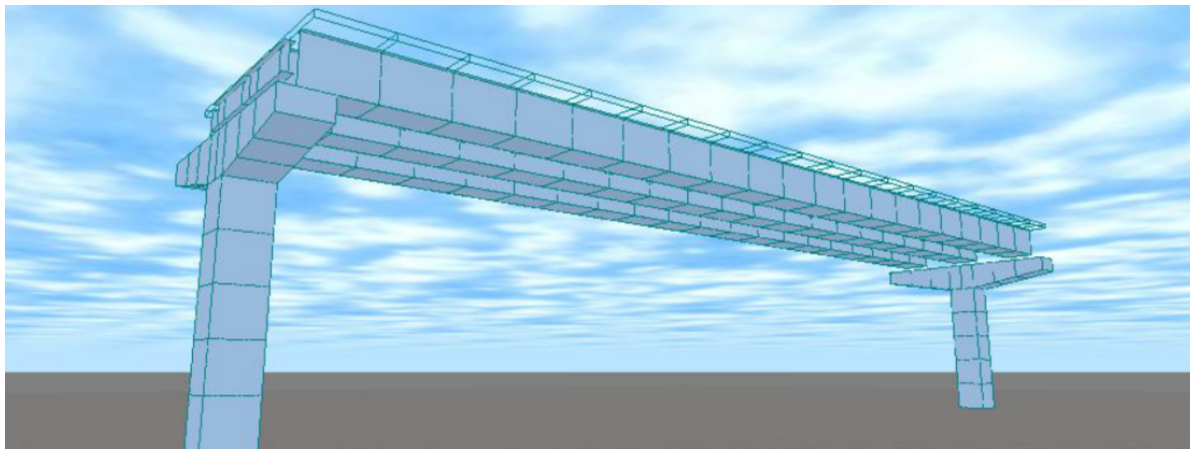


Figure 1. Design Elevated toll Road Using Steel based^[4]

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This paper explain about the experience of Krakatau steel developing HSLA 520MPa class application for Steel Box Girder Elevated Toll road MBZ.

II. PRODUCT REQUIREMENT & ELEVATED TOL MBZ

Many aspects will be considered to build a new elevated toll road such US Weight of structure, Full capacity load, wind, material, design, earthquake, also combination many loads that happen on the elevated road.

II.1 Product Requirement

One of requirement for steel box girder refers to JIS G3106 SM520B, the requirement of chemical composition and mechanical properties including CE maximum 0,40% and PCM maximum 0,26%. is shown in table 1. And table 2. Furthermore there are some requirement coming from customer especially for charphy test is tested at -12°C with minimum average value 41 Joule compare to JIS standard only minimum 27 J at 0°C with V-notch test piece in rolling direction.

Table 1 Chemical Requirements and Target

Elements	JIS G3106 SM 520B ^[1] (%wt, max)	Typical PTKS Design
C	0,20	0,16 - 0,18
Mn	1,60	1,4 - 1,40
Si	0,55	0,03 max
P	0,035	0,025 max
S	0,035/0,010 ^(a)	0,010 max
Nb	-	± 0,025
Al Total	-	-
N	-	-
CE (IIW)	0,40 max ^(b)	0,39 max
PCM	0,26 max ^(c)	0,24 max

Note : ^a Customer requirement

$$C_{eq} = C + \frac{Mn}{6} + \frac{Si}{24} + \frac{Ni}{40} + \frac{Cr}{5} + \frac{Mo}{4} + \frac{V}{14}$$

$$P_{CM} = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

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Table 2. Mechanical Properties

Mechanical properties	Unit	Standard Specification ^[1] JIS G3106 SM 520B
Yield Strength	MPa	365 Min
Tensile Strength	MPa	520 - 640
Elongation	%	19 min
Charpy Test, -12°C ^(a)		
▪ Min Average value	Joule	41 min (full size)
▪ Min Shear Area	%	85%

Note : Direction is longitudinal to rolling direction

(a) Technical requirement

II.2 Elevated Toll MBZ

A. Background Elevated toll

Elevated toll Mohammed bin Zayed , which located in located in the middle of the Jakarta-Cikampek was inaugurated by President Joko Widodo on December 12, 2019. There are 36.84 kilometres of cross along Bekasi City, Bekasi Regency, and Karawang Regency, West Java, Indonesia. The purpose of the construction of this toll road is to separate the Jakarta-Bekasi-Cikarang commuter line (collector/existing line) with long-distance travel routes to Cirebon, Bandung, Surabaya.

The toll road project uses more than 240 thousand tons of steel from Krakatau Steel. This figure is optimistic that KS can fulfill it, considering that production capacity is around 2,4 Million ton/ Years. The steel used in this project due to having spans more longer till 60 meters compares to 30 meters commonly used in toll roads.

B. Comparison Steel & Concrete

Design of structural members with maximum efficiency & minimum cost is always a challenge to the Architects & Engineers. The most important & frequently encountered combination of construction materials is that of steel & concrete with application in multi-storey building.

RCC(Reinforced Cement Concrete) Structures :

(1) Advantages

- Materials used in RCC construction are easily available.
- It is durable and long lasting.



Figure 2. Concrete

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- It is fire resisting and not attacked by termites.

(2) Disadvantages:

- Scrap value of reinforced members is almost nil.
- Constant checking is required.
- Skilled labour is engaged in the work

Steel Structures :

(1) Advantages

- High Strength – This means that the weight of structure that made of steel will be small.
- Uniformity – Properties of steel do not change as opposed to concrete.
- Elasticity – Steel follows Hooke's law very accurately.

(2) Disadvantages

- Maintenance cost – steel structures are susceptible to corrosion whenever exposed to air water and humidity. They must be painted periodically.
- Steel has very small resistance against fire as compared to concrete.
- Fireproofing cost- Steel is incombustible material however its strength is reduced tremendously at high temperatures due to common fires. ^[2]

C. Trend Market Segment

Construction, Otomotif, Oil & Gas has a different tendency to demand quality. Oil and gas company mostly is project based, even specification is same from API 5L Series the requirement is different in term of chemical and mechanical properties furthermore Pipe manufacturers have their own machine characteristics so they make special requests to form easily.

Automotive sectors have own style to get good quality of steel, not only refers to international standard, but they want to get more strict in term of mechanical properties, size and specific character such as formability, paintability. Their development product needs support from the steel manufacturer due to getting lower thickness of material with higher tensile & yield strength so the vehicles will be more efficient.

There is no significant development in the Construction sectors, only few structure that use special steel such as SM 520B. it can still be optimized by good communication between Designer and Steel Manufacturer, Basically the requirement of construction sectors only refers to international standards even though steel manufacturers is capable to produce stricter than the standards.

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III. PROCESS DESCRIPTION

Krakatau Steel have an Integrated steel facilities which can produce High Strength Low Alloy steel. The explanation of making HSLA Steel SM520 B starts from Steel making-Casting process followed by Hot Rolling to become Hot Rolled Coil.

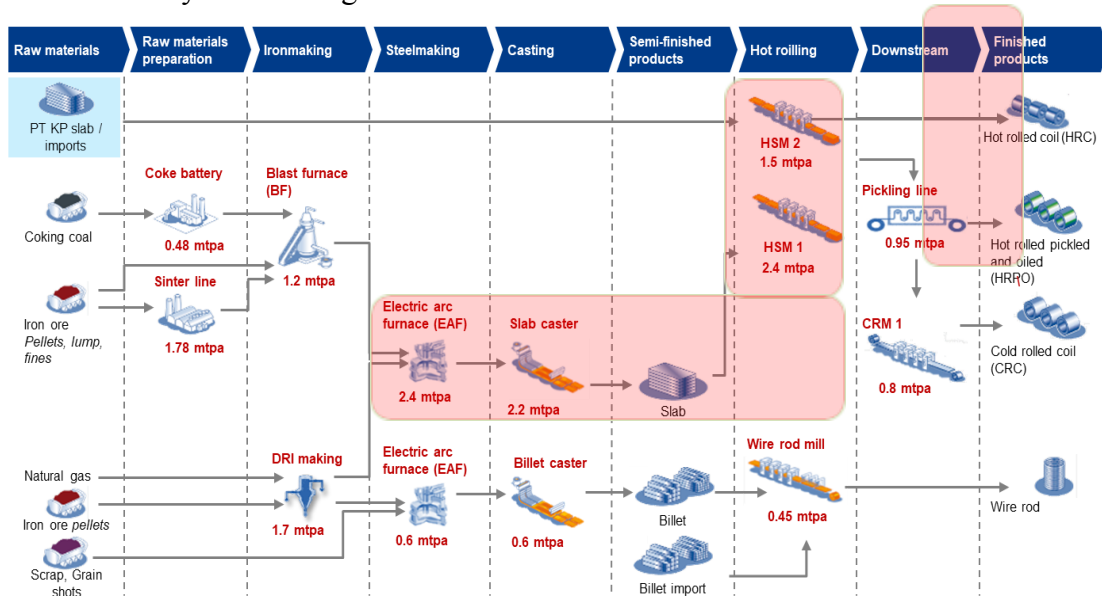


Figure 3. Production Facilities

III.1 Steel Making Process

The main purpose of steel making process is to make good quality of steel slab start from selected raw material, excellence cleanliness practice and smooth casting process. In this stage, aims to obtain a chemical composition not only comply with standard JIS G3106 SM 520B^[1] but also should in range of typical design. shown by Figure 4

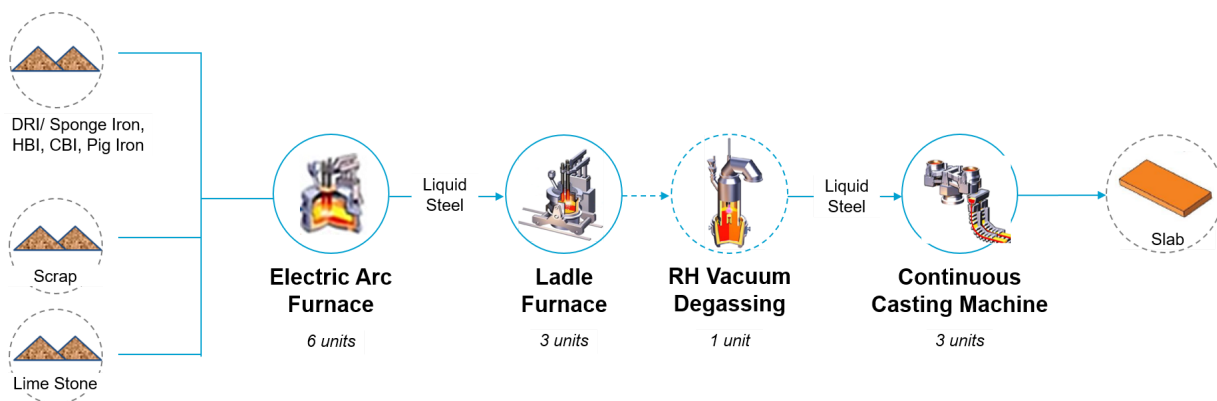
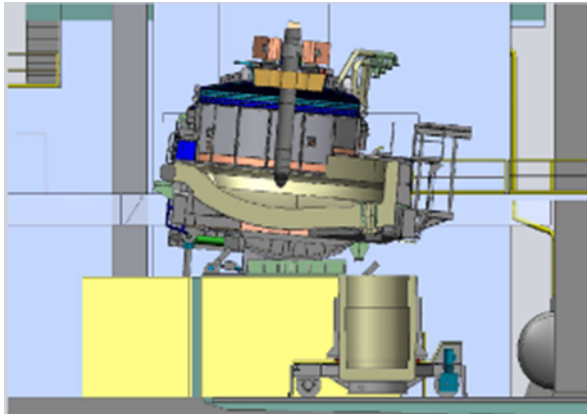


Figure 4. Steel Making & Casting Process

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A. Melting (Electric arc Furnace)

Producing HSLA need high quality in raw material especially scrap. before it processed in Electric arc Furnace scrap selection is done to reduce possibility impurities in molten steel. For these steel mostly using Home scrap to make sure not too much impurities carried out into Furnace.



5 Electric Arc Furnace

of Scrap maximum is 20% and the other is DRI with and 1,8 – 2 by adjusting the slag composition (MgO, to get high quality molten steel with low Oxygen ities and the most important thing is competitive in umention (kg/T)

Some standard operation is applied such us Hot heels >5 Ton, tapping temperature ± 1640 °C, sulphure conten under 0,01%, decreasing phospor content under 0,003% by oxygen injection, de-Carburization until $\pm 0,18$ % C.

B. Ladle Furnace

In the secondary metallurgy process, final adjustment chemical composition is applied by adding some material, alloying element also removing some impurities to get cleanliness steel. The first process in ladle furnace is heating the molten steel up to and Slag making by adding limestone (CaO) around 1000 Kg.



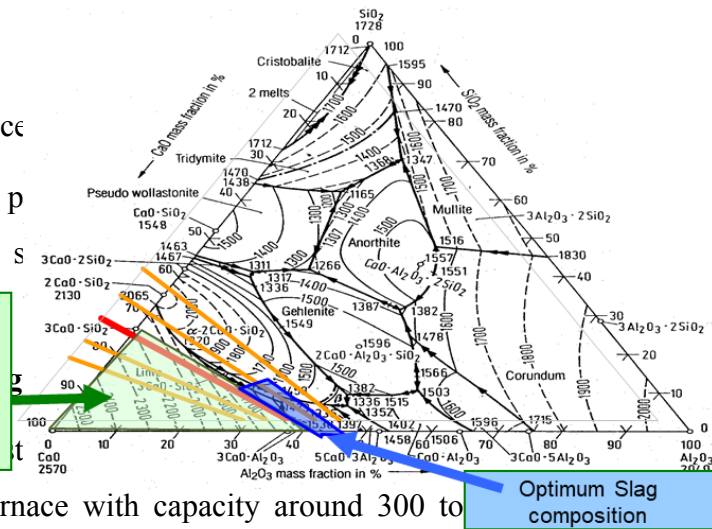
Figure 6. Handling steel after LF treatment

Before doing correction of chemical alloy, killed oxygen must be done with Aluminium Pellet until Al content is much stable parallel with deep desulfurization (figure 7) using high flow of Argon bubling due to maximum sulphur is only 0,01%(100 ppm). Niobium is the only micro alloy which use in these steel grade to increase level strength by making fine grain the last treatment is controlling temperature according to casting temperature and the steel can deliver to casting area (figure 6.)

D. Casting Process

The main purpose is to avoid any defect. No s

This area is not suggested for desulphurization, because the slag viscosity is high and CaO is already over saturated



ization

specific dimension without
ure to casting HSLA is

phase in the furnace with capacity around 300 to 500 tons. The technology that use in hot rolling is Thermomechanical control process (TMCP). The main purpose is to get more finer grain size that can improve mechanical properties especially on higher tensile strength and yield strength with better toughness & formability.

The slab in austenite phased reversibly rolled with high reduction from 200-230 mm to become 32-45 mm then reduction more precision in finishing mill with 6 stands thus make the strip size is comply to customer requirement. Laminar cooling section is used to set cooling rate of the strip so it can design mechanical properties according standard JIS G3106 SM520B shown by figure 8

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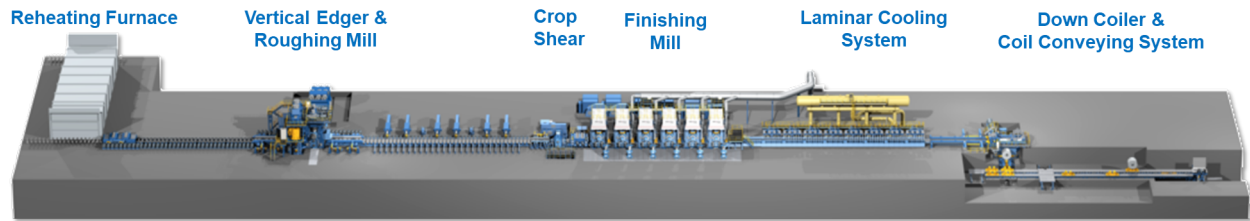


Figure 8. Hot Rolling Process

IV. Result and Analysis

PTKS has been able to produce High Strength Structural steel. The following is one of the results of PTKS experience in producing specification G3106 SM520B.

IV. I Chemical Composition

The chemical composition analysis was carried out in molten steel from casting area (Tundish analysis) with the result is shown in Table 3

Tabel 3. Chemical Composition

Elements	JIS G3106 SM 520B (%wt, max)	Typical PTKS Design	Trial Result
C	0,20	0,16 - 0,18	OK
Mn	1,60	1,4 - 1,40	OK
Si	0,55	0,03 max	OK
P	0,035	0,025 max	OK
S	0,035 / 0,010 ^(a)	0,010 max	OK
Nb	-	± 0,025	OK
Al Total	-	0,02-0,06	OK
N	-	-	OK
CE (IIW)	0,40 max	0,39 max	OK
PCM	0,26 max	0,24 max	OK

Note : (a) Customer requirements

This result shows that the chemical composition are comply with standard^[7] and design KS. Furthermore Sulfur content obtained is around 0,003 with CE and PCM less than KS Design.

IV.2 Mechanical Properties

Tensile tests have been carried out on the end of coil with orientation in the Ingitudinal to rolling direction. The result of tensile test showed that mechanical properties of the coil are in

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accordance not only standard JIS G3106 SM 520B but also Customer Requirement in term of charphy test, it explain in table 4.

Table 4. Result of Tensile Test Gauge Length 50 mm

Mechanical properties	Unit	Standard Specification ^[7]	Head	Midle	Tail
Yield Strength	MPa	365 Min	- 433 - 519 - 525	- 504 - 551 - 518	- 484
Tensile Strength	MPa	520 – 640	- 540 - 544 - 605	- 617 - 618 - 627	- 614
Elongation	%	19 min	- 23 - 23	- 20 - 20	-19

Note : Direction is longitudinal to rolling direction

IV.3 Microstructure

Microstructure observation of the product was also observed by optical microscope showed that the microstructure of product is ferrite & perlite (figure 9)

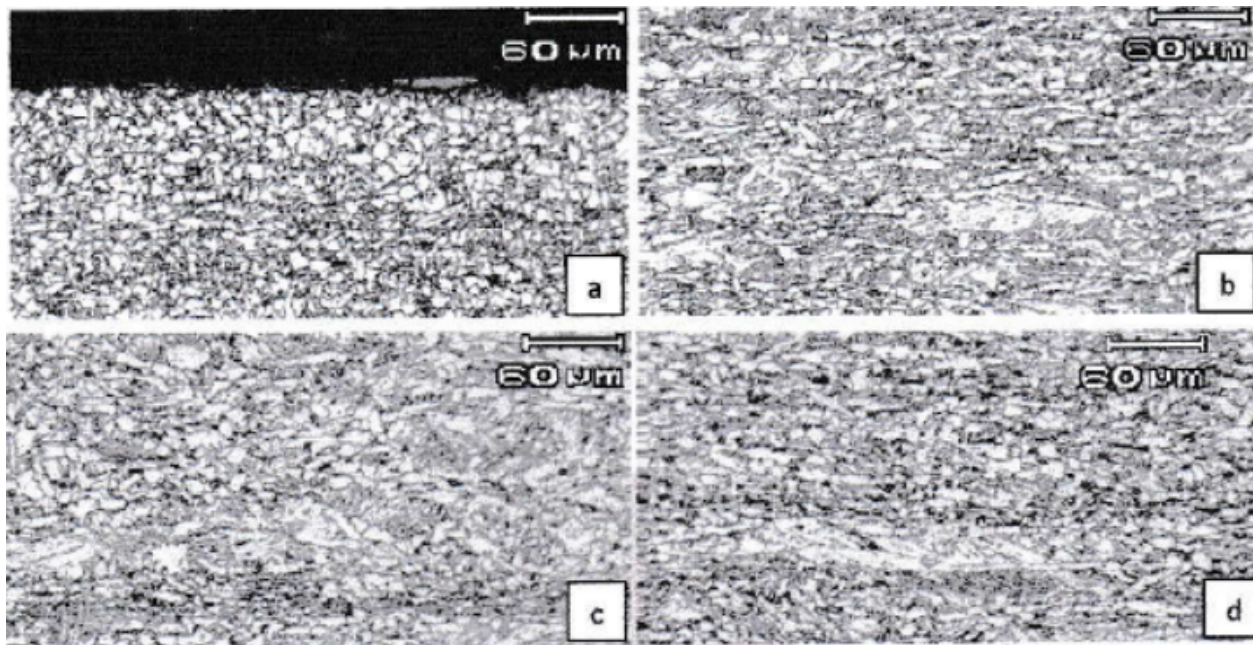


Figure 8. Microstructure

IV.4 Charphy Test

Charphy test is conduct to determines the amount of energy absorbed by a material during fracture. Absorbed energy is a measure of the material's notch toughness. The result shown in table 5

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Table 5. Charphy test

Sample	Specification	Direction	Charphy Absorbed Energy (Joule)			
			+20°C	0 °C	-20 °C	-40 °C
1	SM 520B	L	244	237	225	216
		D	175	190	135	98
		T	175	185	83	112
2	SM 520B	L	203	180	162	109
		D	185	135	151	54
		T	156	158	113	112
3	SM 520B	L	213	212	176	147
		D	186	146	155	69
		T	172	162	111	88

The product has a high charphy absorption energy, meaning that the material is not brittle so that if a failure occurs it will not happen suddenly

V. Conclusion

In regard to Hot Rolled Coil steel produced by PTKS for high strength steel, it can be concluded that:

1. Steel and concrete materials have advantages and disadvantages. Good calculations for material selection will get better results.
2. The Development of HRC Spec JIS G3106 SM 520B by PT KS is successful since Mechanical properties and Chemical properties is comply to standard.
3. PT KS is able to fulfill the order for MBZ elevated toll road girder box with good toughness even in very low temperatures (-40).

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